THE SOIL SCIENCE SOCIETY OF FLORIDA

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PROCEEDINGS VOLUME IX 1948-49

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Annual Meeting of The Society
Clewiston, October 12 and 13, 1948

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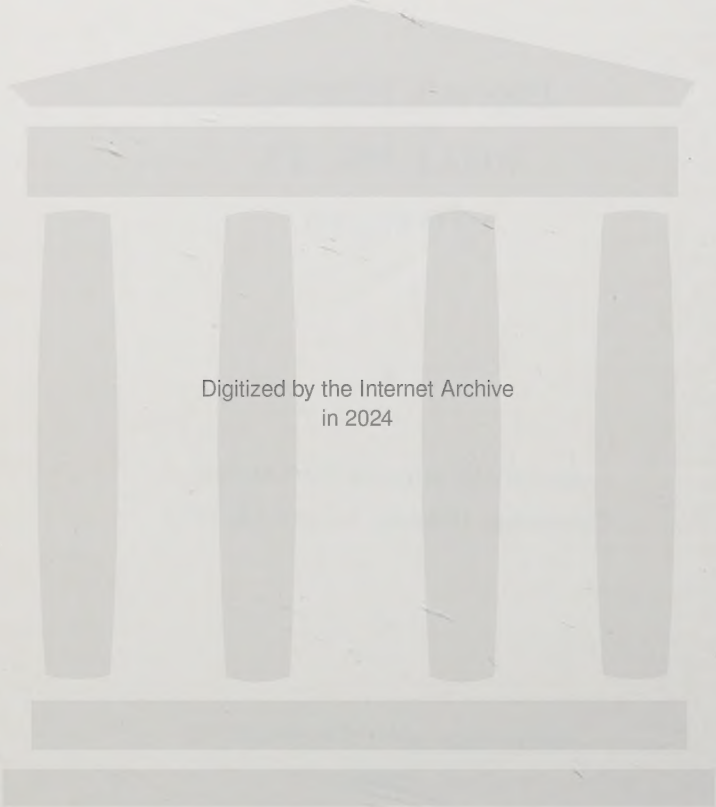

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ACKNOWLEDGMENTS

The Executive Committee of the Society and its entire membership are greatly indebted to Colonel Willis E. Teale, District Engineer, Jacksonville, Florida District, Corps of Engineers, Department of the Army, and his associates for the fine interest they have displayed in the program of the Society, and for the splendid parts they have taken in it; also for his permission to dedicate this volume to him as an expression of appreciation on our part for the splendid work he has done and is doing in connection with the development of a highly coordinated water conservation and control program for Central and South Florida.

We are also greatly indebted to the U. S. Sugar Corporation for its gracious cooperation in allowing us the use of its spacious auditorium and many other facilities which contributed so greatly to the success of the meeting; likewise, to the Manager and his many assistants at the Clewiston Inn who handled the evening banquet in such a fine manner and, otherwise, made our members and their guests feel so much at home during their stay in Clewiston.

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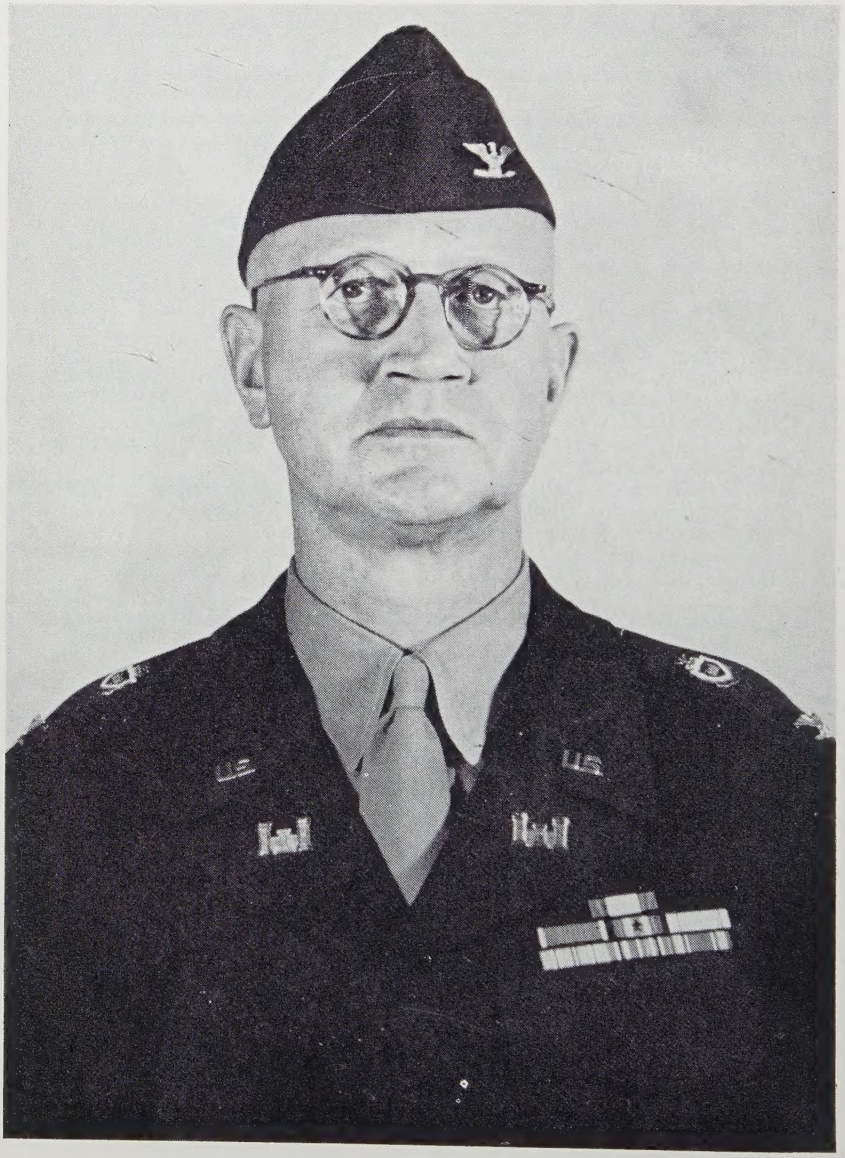

COLONEL WILLIS E. TEALE
District Engineer, Jacksonville, Florida District,
Corps of Engineers, Department of the Army

COLONEL TEALE

Born in Muskegon, Michigan, Colonel Teale was graduated from the U. S. Military Academy in the class of 1917. He came to Jacksonville early in 1947 with a colorful and interesting career, both as a regular Army officer and as an engineer. During the war he organized and commanded the 38th Combat Engineer Regiment and served for two years as Chief Engineer of the U.S. Army Forces in Australia and of the Services of Supply of the Southwest Pacific area. Upon his return from overseas duty, he was named Commanding Officer, Albany Engineer Depot, and in June 1946, Commandant of the Army Engineer School, Fort Belvoir, Va. As Chief Engineer, Army Services of Supply in the Pacific area, Colonel Teale was awarded the Distinguished Service Medal for his superior performance of duties, and also the Legion of Merit for his outstanding services at the engineer school.

His first tour of overseas duty came during World War I in France with the 7th Engineers. In 1923, Colonel Teale continued his engineering studies and completed post graduate work at the Massachusetts Institute of Technology. For two and half years he was on duty as Secretary of the Mississippi River Commission with the Division Engineer in St. Louis, Missouri, where he won recognition in handling flood control works along the Upper Mississippi River.

Colonel Teale had other important assignments, including a two year tour of foreign duty with the American Battle Monuments Commission, Paris, France, assistant to the North Atlantic Division Engineer in New York, District Engineer at Mobile, Alabama, and Associate Professor of Mathematics, U. S. Military Academy.

As District Engineer of the Jacksonville District, Colonel Teale is in direct charge of all river and harbor and flood control work in peninsular Florida. It was under his direction that the Central and South Florida Plan for Flood Protection and Water Control, recently authorized by Congress, was developed and submitted to the Chief of Engineers.

Colonel and Mrs. Teale and their son reside in Jacksonville. Their daughter, Katherine, is attending Vassar College. Mrs. Teale is the former Miss Katherine Farr Brown of Cleburne, Texas.

LEWIS S. EVANS

THE NATIONAL WEED CONTROL PROGRAM

L. S. EVANS*

The losses from weeds and undesirable plant growth are as great in their aggregate importance to the individual as those from insects and plant diseases combined. Weed control constitutes an almost ideal field for cooperative research. No weed control problem is limited to a single State and the local problems are so numerous that no one State can hope to investigate all of them adequately. The keen and widespread public interest in weed control naturally is pleasing to the research worker in this field. The avid interest of the farmer in herbicides is second only to his demand for mechanization. It would be difficult to overestimate what these chemicals imply to the future of agriculture. We are in the midst of further enormous growth in this field. All weed control activities are interdependent and in the process of rapid development. The first requisite is a critical review of the situation as a whole and a statement of the ultimate purpose of the program.

Research on the control of weeds is carried on by a number of agencies within the United States Department of Agriculture, each interested in a certain phase of the work. This discussion will deal primarily with the work of the Bureau of Plant Industry, Soils, and Agricultural Engineering. Weed research in this Bureau is conducted by the Divisions of Farm Machinery, Fruit and Vegetable Crops and Diseases, Forage Crops and Diseases, and Cereal Crops and Diseases, all in cooperation with State Experiment Stations in the various areas. The present research project was initiated in 1935 when a special appropriation was made by Congress for bindweed control investigations. It was organized as a project in the Division of Cereal Crops and Diseases of the above Bureau.

In December 1945 the Department of Agriculture was asked to cooperate with the Office of the Chief Engineers, War Department, on a study of the control of water hyacinth in the Gulf Coastal Area. This project was financed by the War Department.

In 1946 the Congress voted a modest appropriation for a study of the control of nut grass in the southeastern states and as a result work is now underway on this problem in Mississippi and Georgia.

In 1946 funds also were appropriated by the Congress for the study of the control of weeds on ditchbanks, in irrigation

*—Agronomist, Division of Cereal Crops and Diseases, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, U. S. Dept. of Agriculture.

Editor's Note: Mr. Evans used a very extensive series of colored slides in presenting his lecture which, unfortunately, we are unable to reproduce in this published account.

canals, and reservoirs, and on irrigated lands of the West. This appropriation was obtained at the request of and with support from the Bureau of Reclamation of the Department of the Interior. Investigations in this problem are being conducted at field stations located in Arizona, Washington, Idaho, Utah, and Colorado.

With the passage of the Research and Marketing Act of 1946 new funds were made available for weed research work. A project entitled "To establish a cooperative national research program to develop practical methods and equipment for weed control" has been established. In addition to the personnel employed at Beltsville, field representatives in 15 states are now engaged in full time weed control research in cooperation with the various State Experiment Stations. In addition, close liaison is being maintained with the four regional weed control conferences organized throughout the United States. It is now believed that adequate coverage of the weed control problems of the country is being given within the limitations of the funds available. This is not meant to imply that all weed control problems are being attacked simultaneously.

THE APPROACH

The primary objective is the discovery of new facts and accurate interpretation of old ones though not necessarily for immediate practical ends. The keyword in integration. For example, integrated research would involve close liaison between the chemical-weed-killer men and those working in plant research and soil chemistry. Integrated operation means fitting the control to the weed, or the chemical to both crop and soil, or if this cannot be done to breed crop varieties resistant to the chemical. Integrated machinery concerns planning programs, education, and regulatory activities.

There is no lack of initiative on the part of the weed researchers in the field. Weed research is still in a fairly exploratory stage of development from the standpoint of experimental design and methods of analysis. A point of special significance is the present lack of standardized techniques and terminology.

The broad weed control research program includes (1) fundamental or basic studies, and (2) applied or agronomic phases. The fundamental studies will be common to two or more regions and will form a part of the national program of weed control investigations but may have broad consequences in related fields as well. The discovery of the growth regulator herbicides and other improved chemicals has shifted the emphasis on weed control investigations since 1944. These new chemicals are useful tools in any weed control program, but they do not fulfill all requirements. Some of the standard practices of weed control have been overshadowed by the advent of chemical control, but these older methods should not be discarded. Clean cultivation, short rotations, planting clean seed, and quick eradication of

new kinds of weeds that appear still represent reliable and effective methods in the never ending fight against weeds. Proper mowing, fertilization, and other details of pasture management will do much to alleviate the weed problem in pasture and range lands.

The general objective is to develop practical methods, materials, and equipment for the control of weeds. The headquarters of the national weed control program is at Beltsville, Maryland, near Washington, D. C. Basic research on herbicides and their effect on plants is underway at that location. Field investigations are established on a regional basis in cooperation with State Agricultural Experiment Stations and other agencies in each region. Chemical and physiological studies and field studies on competitive cropping, chemical weeding, pasturing, tillage, and other methods of control will be supported under this project in the several regions. Field work on the development of satisfactory mechanical, cultivating, spraying, flaming, electrical, and herbicide applying equipment is centered at Ames, Iowa, St. Paul, Minnesota and Stoneville, Mississippi. Agronomic, ecological, and mechanical investigations will first be undertaken on the major weeds of each region and the results will be made available to all cooperators. In addition to the cooperative work with the experiment stations within the continental United States plans are being made to take advantage of the year around growing conditions in Puerto Rico to permit the continual testing of new materials as to their herbicidal value. New chemicals will be screened in order to determine their herbicidal properties, chemical stability, toxicity to animals, inflammability and other characteristics. Studies will be conducted to establish and standardize indicator plants for evaluating herbicides.

A relatively small group of scientists have considered the basic weed control problems from the standpoint of deductive reasoning, while a much larger group approach the problem from the empirical or cut-and-try viewpoint. They have not yet reached common ground. Nevertheless the proper place exists for each approach. Empirical investigations have produced most of our information on weed control practices in current use. In this connection, it is pertinent to note that the direct assault in science is sometimes the least successful, while it is legitimate to keep searching for curative agents for weed pests it is quite certain in the long run that more will be gained by broadening the base of fundamental knowledge of weed behavior. This somewhat tedious spade work is now moving forward slowly in Beltsville and in other research institutions supported by public and private funds.

THE ACCOMPLISHMENTS

In a joint discovery by the personnel of our Bureau and the Bureau of Reclamation at the Denver Chemical Laboratory of the latter it was found that the carrier used in one of the pro-

prietary 2, 4-D compounds was toxic to aquatic weeds. When the carrier was analyzed the toxic constituent proved to be a coal tar naptha. Later a cheaper petroleum naptha was found to be just as effective and could be used at one tenth the cost of the chemical methods now in use. Extensive field scale trials of the new process are now underway in the water delivery systems of the irrigated southwest.

A different type of weed control is being studied in our nut grass investigations. Ethylene dibromide and chloropicrin, both highly volatile liquids, are being used as soil fumigants. Thus far they have been more effective though more expensive than any method of control by tillage or smother cropping. Nut grass cannot be eliminated simply by spraying with 2, 4-D because the effect generally does not extend below the basal bulb and the first tuber.

Considerable attention and emphasis has been given recently to the control of weeds in row crops by pre-emergence chemical treatment. Two methods have been employed. (1) Application of a selective herbicide to the soil at the time of seeding. The chemical in the soil kills weed seedlings but those of crop plants are uninjured. (2) Application of a general contact herbicide to a population of weed seedlings prior to the emergence of the crop seedling or prior to the seeding of the crops. Pre-emergence weed control is possible because as a rule only those weed seeds that are within the ¼ to ½ inch of soil germinate. If the initial population of weed seedlings is destroyed without disturbing the soil and thus bringing more weed seeds near the surface, very few weeds will be present to interfere with the early growth of the seedling of the crop. Advocates of pre-emergence weed control recognize the fact that the early competition of weeds with crop seedlings is a factor of great significance.

Pre-emergence spraying with 2, 4-D under some conditions controls practically all kinds of annual weeds including grasses but there is much to be learned about its proper use. Soil applications of 2, 4-D at the rate of 2 pounds per acre effectively controlled weeds for a period of six weeks in crops such as corn, soybeans, lima beans, and peanuts. Dinitro compounds have been similarly successful on crops sensitive to 2, 4-D such as cotton and some vegetable crops. Pre-emergence weeding is more often hazardous on sandy soils than on clay soils because of the deeper percolation of the chemical into the soil. The rate of inactivation of the chemical by the soil may also be a factor in this case. In heavy soils the chemical does not reach deep planted crop seedlings in time to cause serious crop injury but may cause severe injury or death to the shallow germinating weed seeds. Research is continuing to determine the relationship of factors such as rainfall and soil moisture to the success of the treatment.

Ammonium trichloroacetate has shown promise as an effective perennial grass killer when applied at rates of from 100 to 150

lbs. per acre. When applied to the soil this chemical has a somewhat selective effect on the perennial grasses but when applied as a foliage spray it behaves as a non-selective herbicide. Selected fractions of the aromatic petroleum compounds have been found to be considerably more effective in controlling Bermuda grass and Johnson grass in the irrigated sections of the southwest than has ordinary diesel oil. These materials are now being used extensively for the control of undesirable vegetation on irrigation ditchbanks. These materials are non-selective in their action and since they serve only as contact killers, 4 to 5 applications may be required to completely destroy established stands of the perennial grasses. Diesel oil, which has commonly been used in many sections of the West for the control of unwanted vegetation, is now being fortified with such compounds as pentachlorophenol or the dinitro phenols. The addition of these extenders may be expected to alleviate the present oil shortage to some degree.

A significant development in weed control has been low volume applications of spray. Whereas formerly we thought in terms of 100 to 300 gallons of liquid applied to the acre we now are using successfully volumes as low as 3 gallons (or even less) per acre. Low volume applications have been made possible by improvement in equipment, particularly nozzles, and by taking advantage of the translocating characteristic of 2, 4-D and other growth regulating herbicides. Low volume applications are especially valuable in areas where water is scarce and where hauling and refilling add materially to the cost of application.

THE PROSPECT

Three points can be made about weed control as a science. It is the youngest science although actually, in a crude form, it stretches back into antiquity. It is in the midst of further enormous growth and it is in a crisis that reflects the preoccupation of the average American with the idea of "pill" farming. In some cases weed control is the last bottleneck to the complete mechanization of some farming operations, notably cotton and sugarcane culture. The weed researchers began to appear in numbers in 1936 but as a distinct class his origin began in 1944 with the premature announcement of 2, 4-D. These are the challenging facts which provide a sense of urgency underlying the whole profession. Chemical weed control is not a substitute for good farming—it is a part of good farming.

Spectacular growth is nothing new in the sciences. The War prepared the ground for the great efflorescence in other scientific fields and its surprising proliferation in our own. The days of improvisation are not gone but laymen are beginning to ask pertinent questions about the "why" of things. While it is true that we don't have to know the cause of fire before efforts are undertaken to extinguish it, we cannot accurately appraise our

accomplishments in weed control as long as we are troubled by the lack of basic research. We are still too engrossed with the details to be able to explore the field with the objective and leisurely contemplation which is accepted as the measure of the true scientist.

We are close to something new and revolutionary and universally important. The underlying idea of non-cultivation is not new—but now for the first time through the use of chemicals we have available means of controlling weeds without resorting to some of the inefficient and disadvantageous tillage practices which have prevailed through generations. The new system may not be foolproof but the errors, for the most part, are self-correcting. The inherent possibilities have not yet been realized but they are limited only by the spontaneity, ingenuity, and original creativeness of the research workers concerned.

SYMPOSIUM I

THE CONTROL OF WATER PLANTS FROM THE STANDPOINT OF WATER MANAGEMENT AND NAVIGATION IN THE LAKES, RIVERS AND CANALS OF THE SOUTH

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THE GENERAL CHARACTERISTICS OF THE PRINCIPAL PLANTS INVOLVED

ERDMAN WEST*

There are many plants in the South that inhabit navigable waters, their margins and their tributaries. If we are to discuss the problem of their control, we must know something about the characteristics of these plants. It is not necessary to list, let alone discuss, every species that might be found in this environment. In the mild climate of this area, there are so many kinds that there would be little time for any discussion of their control. Moreover, many of them are so rare or local that they are of very minor importance. It will be more practical from all standpoints to confine our consideration to the more numerous and hence more important species. If we divide these according to habitat, we can simplify our problem still further. I believe control measures are likely to follow this sort of classification rather closely too. I would like to put them into three categories and call them floaters, bankers and sinkers.

FLOATERS

The first division will be called "floaters" because they float on the surface of the water and grow without the necessity of any attachment to the soil. Normally, they float freely and move with the surface currents of the water. In shallow areas or margins their roots may anchor them in the mud. The most ubiquitous is, of course, the common introduced water hyacinth. It has long been the most pestiferous plant in navigable waters and millions of dollars have been spent, more or less futile, in attempting its control. The discovery and use of 2, 4-D weed killer has changed this picture very materially. Water hyacinth floats by means of the inflated petioles or stalks of its leaves and multiplies rapidly by offshoots. How much reproduction occurs from seeds is not well known.

A native floating plant, water lettuce, has many of the general characteristics of water hyacinth, but it does not multiply nearly as rapidly. Each plant bears many flat, pale green, leaves in the form of a rosette. The flowers are small, inconspicuous, greenish-white, hairy and funnel-shaped.

Another native aquatic, frogbit, is far less common but may

*—Botanist, Florida Agricultural Experiment Station, Gainesville.

Figure 1.—FLOATERS—This tremendous growth of water hyacinths is typical of the "Floater" group of water weeds. The Hillsboro Canal is under this heavy mat and, of course, greatly reduced in its capacity to handle drainage and irrigation waters. The measuring stick at the left, which is held at the water's level, shows the height of the plants to be nearly 3 feet. Photo taken in front of the Everglades Experiment Station looking towards Belle Glade on October 24, 1935.

be locally abundant. The leaves are shaped like water hyacinth leaves, but the base of the leaf blade is spongy and the leaf stalk is slender. The flowers are small and white, resembling small spiders. It multiplies by producing offshoots or lateral stems 4 to 6 inches long. Large colonies are often inter-connected by these horizontal and slightly submerged stems. At some seasons of the year, numerous seeds are released.

In densely shaded areas the floating fern may cover considerable areas, in patches as much as 20 feet across. The vegetative leaves float on the surface of the water and produce young plants along their margins. Even small pieces broken off may drift away and develop a new plant. The whole plant is brittle and easily broken up.

Among the smaller plants are the duckweeds and floating fern allies. Any one of these, alone or in combination, may cover the surface with the small plants individually less than one-fourth inch across. Spirodela and Lemna are the common native duckweeds found nearly everywhere. The fern allies are introduced plants called Azolla and Salvinia. The character that makes these plants particularly obnoxious is their small size. Rakes and most nets are useless because the plants slip through the meshes so that they cannot be removed mechanically.

Figure 2.—BANKERS—The heavy growth of Para grass extending from both banks of the Hillsboro Canal to a point of nearly closing it is a good example of this type of water weed. Photo taken in Belle Glade from the main bridge looking towards Lake Okeechobee, June, 1948.

BANKERS

The second division of aquatic plants with which we are dealing is called the "bankers" because they must have their roots in the soil of the banks or margins of the body of water invaded. Their stems are usually hollow or inflated so that they float on or near the surface and may extend out ten or more feet from the bank where the root-system is embedded. They often extend out from both banks and completely cover canals or small streams.

One of the most important of the bankers, at least here in the Everglades, is the introduced Para grass. This grass grows vigorously on moist soil and produces great numbers of long runners or horizontal stems. On land, they root at every joint that touches the soil but on the water they float near the surface and increase in length.

There are several native grasses that act in much the same manner. Fall panic grass and swamp grass are two of the larger growing kinds that may extend 6 to 8 feet from the bank. Two others that are much less vigorous in growth are creeping paspalum and water grass.

Another vigorous and prolific plant in this category is water pennywort. This aquatic with round leaves attached at the center has inflated stems and leaf stalks which enable it to float easily. In quiet water these floating runners may extend 20 feet from the bank or point of attachment. Seeds are produced in

great quantities and float readily to new locations. Newly invaded ponds or streams are quickly populated.

An introduced weed has shown itself to be potentially the most dangerous of this group. This is the dreaded alligator weed. It has become established in only a few places in Florida, and so far has not occupied much area in this State but elsewhere it has proved to be a major pest. It has narrow leaves and terminal heads of small silvery-white flowers.

One of the smartweeds, portorican, is a valuable food plant for ducks but it can also extend out from banks or islands and cover considerable areas of water too.

Watershield with its oval leaves and jelly-covered stems is not a very vigorous grower but is often a pest in lakes.

An introduced aquarium plant known as parrot's feather is a vigorous grower. It is frequently thrown out by gold fish growers when it becomes too abundant in their pools or aquaria. Such discarded material can quickly create a hazard if it is thrown into a stream or other body of water. It has very finely cut bluish-green leaves.

SINKERS

The third division has been named "sinkers." These, strictly speaking, do not sink but they do have their roots in the bottom of whatever body of water they invade. They constitute the most insidious of the pests because they are submerged and hence inconspicuous but they nevertheless greatly impede water flow and slow down navigation.

One of the most common in this group is coontail, incorrectly called moss or coontail moss(it is not a true moss). It forms large plumy or ball-shaped masses of stems and narrowly segmented leaves. It is dull, dark green in color but the growing tips are often pinkish.

In some areas, naiads are more common. This is more grass-like with thin wiry stems and short narrow leaves, but it grows to great length and covers vast areas of bottom with a dense growth. It is very common in lakes and canals.

In shallow water, the pondweeds can become pests. Some of these invade brackish water as well as fresh. They vary much in leaf size and shape but all species are characterized by cone-like flower clusters.

Some other submerged aquatics such as bladderworts, cabomba and elodea are locally common and troublesome.

SUMMARY

This is a brief consideration of the plants involved in the management of water for navigation, conservation or other purposes. In general, the habits of the plants as groups seem more important than the botanical characteristics of the species. As tolerances or immunity to specific chemicals become more apparent, certain species may become more important or demand

Figure 3.—SINKERS—This dense growth of the so-called "nigger wool" (*Najas guadalupensis* (Spreng.) Morong.) that practically fills the entire cross section of these drainage canals is a good example of the submerged or "Sinker" type. It is even worse than a hyacinth cover because it almost stops all flow and actually blocks the canal until removed. Above—in the Clewiston area; Below—in the Davie area under pumpdown conditions with flow lines showing along the surface of the weed.

special treatment, but for the present they can be treated in the groups we have outlined. The scientific names of the weeds referred to above are listed below under the three groupings which have been adopted for convenience in discussion.

FLOATERS

Water hyacinth	*Eichornia crassipes* Mart.
Water lettuce	*Pistia stratiotes* L.
Frogbit	*Limnobium spongia* (Bosc.) L. C. Rich.
Floating fern	*Ceratopteris pteridoides*
Duck weeds	*Lemna* spp.

BANKERS

Para grass	*Panicum purpurascens* Raddi
Fall panic grass	*Panicum dichotomiflorum* Michx.
Swamp grass	*Panicum paludivagum* H. & C.
Water grass	*Hydrochloa* sp.
Creeping paspalum	*Paspalum repens* Berg.
Water pennywort	*Hydrocotyle* spp.
Alligator weed	*Achyranthes philoxeroides* (Mrt.) Standley
Portorican smartweed	*Polygonum portoricense* Bertero
Watershield	*Brasenia schreberi* Omel.
Parrot's feather	*Myriophyllum proserpinacoides* Gill.

SINKERS

Coontail	*Ceratophyllum demersum* L.
Naiad	*Najas guadalupensis* (Spreng.) Morong.
Pondweeds	*Potamogeton* spp.
Bladderworts	*Utricularia* spp.
Cabomba	*Cabomba caroliniana* A. Gray
Elodea	*Anacharis* spp.

DISTRIBUTION OF WATER HYACINTH IN FLORIDA

JAMES A. HAMMACK*

JAMES A. HAMMACK

The Jacksonville District of the Corps of Engineers recently completed a survey of the entire State of Florida to determine the extent and concentration of the hyacinth and other marine vegetable growth. Authority for this investigation is contained in a resolution of the Committee on Rivers and Harbors of the House of Representatives adopted 6 February 1945.**

A conference of the South Atlantic Division Committee on Hyacinth Eradication and Control was held in Atlanta, Ga., 11 and 12 February 1946. It was decided that aerial photos would be carried on observation flights at low altitude and detailed data recorded on the photos as far as practicable.

An inventory was taken of aerial photographs in the District Engineer's files and it was found that there were about 22,000 square miles to a scale of 1:20,000 to 24,000, also 7,800 square miles at 1:40,000. From commercial sources and various governmental agencies, photographs of the remaining part of Florida with the exception of a part of one county were obtained. In view of the large number of individual photographs, the overlapping coverage, and the anticipated difficulty in handling these small individual photographs in an airplane, it was decided to assemble the photographs into mosaics and photostat them to a uniform 1:20,000 scale on sheets 18″ x 24″, accordion folded and

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*—Engineer, Corps of Engineers, U. S. Engineer Office, Jacksonville.

**—COMMITTEE ON RIVERS AND HARBORS, HOUSE OF REPRESENTATIVES U. S., WASHINGTON, D. C., RESOLUTION

Be it resolved by the Committee on Rivers and Harbors of the House of Representatives, United States, That the Board of Engineers for Rivers and Harbors created under Section 3 of the River and Harbor Act, approved June 13, 1902, be, and is hereby requested to review the reports on Water Hyacinth Obstructions submitted in House Document Numbered 91, 55th Congress, 3d Session, with a view to determining (a) whether any expansion of the scope of operations, or any change in the method now employed, for exterminating and removing the hyacinth plants and other marine vegetable growths from the waters of Louisiana, and such other States as

TABLE 1—Distribution of Alligator Weed and Pickerel Weed in Florida, by Counties

County	Alligator weed (acres)	Pickerel weed (acres)	County	Alligator weed (acres)	Pickerel weed (acres)
1 Alachua	0	907	35 Lake	0	8
2 Baker	0	2	36 Lee	0	1
3 Bay	0	0	37 Leon	0	586
4 Bradford	0	24	38 Levy	0	6
5 Brevard	0	137	39 Liberty	0	1
6 Broward	0	12	40 Madison	0	294
7 Calhoun	0	0	41 Manatee	0	180
8 Charlotte	0	33	42 Marion	0	40
9 Citrus	0	0	43 Martin	0	0
10 Clay	0	74	44 Monroe	0	0
11 Collier	0	9	45 Nassau	1	26
12 Columbia	0	9	46 Okaloosa	0	0
13 Dade	0	11	47 Okeechobee	0	1
14 DeSoto	0	14	48 Orange	0	1
15 Dixie	0	0	49 Osceola	0	1,414
16 Duval	19	2	50 Palm Beach	0	20
17 Escambia	0	0	51 Pasco	0	122
18 Flagler	0	37	52 Pinellas	0	11
19 Franklin	1	1	53 Polk	0	1
20 Gadsden	0	0	54 Putnam	0	45
21 Gilchrist	0	0	55 St. Johns	2	9
22 Glades	0	148	56 St. Lucie	0	1
23 Gulf	0	0	57 Santa Rosa	0	0
24 Hamilton	0	12	58 Sarasota	0	53
25 Hardee	0	427	59 Seminole	0	213
26 Hendry	0	1	60 Sumter	0	0
27 Hernando	0	109	61 Suwannee	0	30
28 Highlands	0	319	62 Taylor	0	523
29 Hillsborough	0	381	63 Union	0	3
30 Holmes	0	1	64 Volusia	1	58
31 Indian River	0	1	65 Wakulla	0	113
32 Jackson	0	3	66 Walton	0	0
33 Jefferson	0	867	67 Washington	0	61
34 Lafayette	0	2			
			Total	24	7,364

so marked as to permit rapid handling in a small space while flying. Each photostated sheet was numbered and in the margins the numbers of the surrounding sheets were indicated. The sheets were assembled by counties and index maps prepared for

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are affected, is advisable at this time; (b) the nature and extent of the various public benefits that would accrue from such extermination and removal, and (c) the amount of local cooperation that may be warranted by reason of the local benefits.

Be it further resolved that this action be taken with the view of determining the estimated cost of permanently eliminating the hyacinth plants and other marine vegetable growths from these streams, and that the cooperation of the Fish and Wildlife Service of the Department of the Interior, and of the Department of Agriculture and the United States Public Health Service be solicited, since the aforementioned obstruction of such streams affects the fishing industry, agriculture and health conditions.

Adopted February 6, 1945. Attest: J. H. McGann, Clerk.

each county showing the coverage of each photostated sheet on a 1-page map of the county.

An effort was made to find some organization that had completed a large-scale reconnaissance survey of this nature from an airplane, but none was found. Through the courtesy of a local flying service a test flight was made to determine conditions which would be encountered and the type of flying equipment best suited for aerial observers. It was decided that a light, high-wing monoplane, with side-by-side seating arrangement, was desirable. Such a seating arrangement permits the pilot and observer to use the same set of aerial maps to maintain a predetermined flight pattern. It was specified that the plane would have a cruising speed of 100 miles per hour, capable of maintaining safe flying speed at 60 miles per hour. The view from a plane of this type is excellent, affording a wide angle of vision approaching 180 degrees.

Both aerial observers selected from the personnel of the District Office had many hours of contact flying over this State. Although ability to fly was unnecessary, as a plane with pilot was contracted for, it was considered desirable that the observer be able to quickly and readily spot and keep his position and direction on the photos. Further, it was thought that persons used to flying in light planes would be less inclined to be bothered by its motions on bumpy air.

Aerial observation was commenced June 3, 1946, and continued until terminated September 17, 1946, in compliance with a Presidential Economy Order. Work was resumed June 4, 1947, and observation from single-engine plane completed July 30, 1947. A total of about 46,000 square miles was covered in a single-engine plane in about 410 hours' flying time. The Everglades part of the State was covered using a twin-engined plane for safety, as recommended by the Civil Aeronautics Authority. In all, a total of about 59,000 square miles of survey was completed August 7, 1947, in 486 hours' flying time, at an average of about 120 square miles per hour. This coverage was made possible by good mechanical performance of the planes and close cooperation of the pilots and Government observers. Much of the observation was made at an elevation of about 500 feet, with some at higher and lower altitudes. The location and density of infestation were marked on the photostat maps as the area was traversed by the plane.

The aerial survey work was checked by ground reconnaissance using two parties of two men each in automobiles carrying the photostats marked by the aerial observers.

Results of this survey are shown on these maps and tabulations of findings are included on these tables. Areas are ex-

TABLE 2—Distribution of Water Hyacinth in Florida by Counties Showing Accessibility, Concentration, and Waterway Use

County	Accessibility			Concentration				Waterway Use				Total water hyacinth
	Easy (acres)	Difficult (acres)	Inaccessible (acres)	Sparse (acres)	Moderate (acres)	Dense (acres)	Very dense (acres)	Navigable (acres)	Non-Navigable (acres)	Drainage Ditches (acres)	Lakes and Ponds (acres)	(acres)
1. Alachua	262	635	899	540	46	1,069	141	1	8	108	1,679	1,796
2. Baker	0	0	0	0	0	0	0	0	0	0	0	0
3. Bay	0	0	0	0	0	0	0	0	0	0	0	0
4. Bradford	2	0	0	0	2	0	0	0	0	0	2	2
5. Brevard	246	53	4	57	36	18	192	0	164	80	59	303
6. Broward	684	0	150	8	96	390	340	0	48	786	0	834
7. Calhoun	0	0	0	0	0	0	0	0	0	0	0	0
8. Charlotte	36	0	148	5	49	125	5	0	27	20	137	184
9. Citrus	258	1,866	0	0	982	1,142	0	344	0	0	1,780	2,124
10. Clay	121	32	45	0	117	71	10	121	77	0	0	198
11. Collier	219	222	2	3	8	36	396	0	0	0	443	443
12. Columbia	0	795	14	38	76	616	79	10	0	0	799	809
13. Dade	121	0	0	2	13	42	64	0	0	116	5	121
14. DeSoto	341	401	291	0	86	67	880	0	1,032	1	0	1,033
15. Dixie	50	19	142	6	192	13	0	203	6	0	2	211
16. Duval	245	8	0	8	74	127	44	237	8	0	8	253
17. Escambia	0	0	0	0	0	0	0	0	0	0	0	0
18. Flagler	115	43	20	0	165	13	0	33	5	15	125	178
19. Franklin	0	25	0	1	0	24	0	0	25	0	0	25
20. Gadsden	290	35	0	0	325	0	0	0	0	0	325	325
21. Gilchrist	0	0	20	0	20	0	0	0	20	0	0	20
22. Glades	373	10	1,271	630	139	762	123	0	509	482	663	1,654
23. Gulf	0	2	0	2	0	0	0	0	2	0	0	2
24. Hamilton	0	6	0	0	0	6	0	0	0	0	6	6
25. Hardee	60	6	411	67	11	335	64	0	136	6	335	477
26. Hendry	73	0	98	3	64	92	12	0	0	158	13	171
27. Hernando	12	284	36	0	169	163	0	178	0	0	154	332
28. Highlands	1,946	1,182	3,841	1	1,969	2,801	2,198	0	6,645	114	210	6,969
29. Hillsborough	877	59	810	62	109	1,162	413	406	620	67	653	1,746
30. Holmes	0	0	0	0	0	0	0	0	0	0	0	0
31. Indian River	115	0	2	1	3	44	69	73	40	4	0	117
32. Jackson	0	0	0	0	0	0	0	0	0	0	0	0

34. Lafayette	0	0	0	0	0	0	0	0	0	0	0	0
35. Lake	488	88	1,084	79	1,222	359	0	338	707	0	615	1,660
36. Lee	43	0	0	6	1	15	21	0	14	29	0	43
37. Leon	73	87	0	48	112	0	0	0	23	0	137	160
38. Levy	681	39	285	634	339	32	0	703	47	0	255	1,005
39. Liberty	0	0	0	0	0	0	0	0	0	0	0	0
40. Madison	0	7	0	1	4	1	1	0	4	0	3	7
41. Manatee	547	0	36	21	370	162	30	0	360	14	209	583
42. Marion	233	131	0	17	172	114	61	3	75	83	203	364
43. Martin	106	0	1	6	13	76	12	10	2	52	43	107
44. Monroe	0	0	0	0	0	0	0	0	0	0	0	0
45. Nassau	88	13	20	10	36	37	38	101	19	0	1	121
46. Okaloosa	0	0	0	0	0	0	0	0	0	0	0	0
47. Okeechobee	1,491	1,399	4,417	0	5,338	1,804	165	0	6,467	803	37	7,307
48. Orange	1,456	140	153	142	159	261	1,187	0	286	26	1,437	1,749
49. Osceola	199	10	1,723	99	500	225	1,108	0	1,353	42	537	1,932
50. Palm Beach	2,842	470	2,566	1,351	1,746	2,484	297	0	37	2,561	3,280	5,878
51. Pasco	690	286	1,532	7	207	2,051	243	0	1,818	0	690	2,508
52. Pinellas	12	92	0	1	1	92	10	0	1	0	103	104
53. Polk	5,828	631	3,888	52	1,745	3,296	5,254	0	2,937	127	7,283	10,347
54. Putnam	1,177	328	140	31	993	621	0	1,186	133	23	303	1,645
55. St. Johns	103	37	28	12	10	134	12	126	32	8	2	168
56. St. Lucie	447	0	84	3	34	61	433	0	269	262	0	531
57. Santa Rosa	0	0	0	0	0	0	0	0	0	0	0	0
58. Sarasota	534	0	75	7	64	520	18	0	352	14	243	609
59. Seminole	695	7	251	6	59	522	366	106	348	0	499	953
60. Sumter	783	981	0	0	1,764	0	0	1,715	0	24	25	1,764
61. Suwannee	0	28	0	0	15	13	0	0	0	0	28	28
62. Taylor	0	0	6	0	2	4	0	0	1	0	5	6
63. Union	0	0	0	0	0	0	0	0	0	0	0	0
64. Volusia	1,906	348	821	0	2,273	799	3	837	411	88	1,739	3,075
65. Wakulla	0	0	0	0	0	0	0	0	0	0	0	0
66. Walton	0	0	0	0	0	0	0	0	0	0	0	0
67. Washington	0	0	0	0	0	0	0	0	0	0	0	0
Total	26,868	10,809	25,314	3,967	21,934	22,801	14,289	6,731	25,068	6,113	25,079	62,991

Note—The above information is based on aerial and ground reconnaisance of the entire State of Florida, conducted in 1946 and 1947.

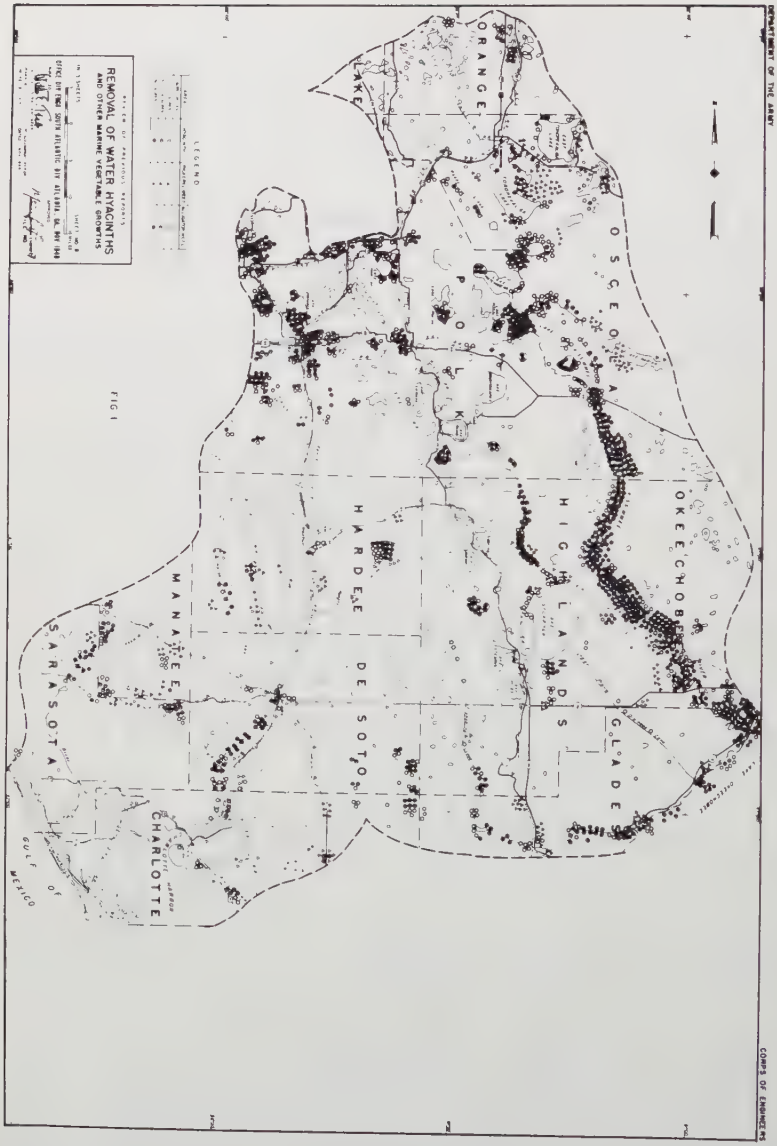

Figure 1.—Sheet No. 8 of 13 sheets covering hyacinth survey of the Southeast (10 sheets for Florida) by the U. S. Engineer Division Office in Atlanta and District Office in Jacksonville. The Kissimmee Valley is conspicuous for the heavy growths that are to be observed up and down its broad and irregular channelway.

TABLE 3—Distribution of Water Hyacinth, Pickerel Weed, and Alligator Weed, by Watersheds

	Hyacinth	Pickerel weed	Alligator weed
St. Johns River and related areas	9,504	569	22
Suwannee River	1,363	137	0
St. Marys River	2	16	0
Nassau River	142	13	1
Total above rivers and related areas	1,507	166	1
Apalachicola River	27	5	0
Ochlochnee River	485	68	1
St. Marks River	3	1,380	0
Aucilla River	9	265	0
Econfina River	0	153	0
Fenholloway River	2	478	0
Steinhatchee River	3	42	0
Total above rivers and related areas	529	2,391	1
Choctawhatchee River	0	62	0
Perdido River	0	0	0
Escambia River	0	0	0
Black Water River	0	0	0
Yellow River	0	0	0
Total above rivers and related areas	0	62	0
Oklawaha River	3,978	934	0
Waccasassa River	256	6	0
Whithlacoochee River	7,442	51	0
Total above rivers and related areas	11,676	991	0
Hillsboro River	2,116	548	0
Alafia River	1,428	36	0
Manatee River	181	30	0
Total above rivers and related areas	3,725	614	0
Kissimmee River	21,113	1,762	0
Peace River	6,478	676	0
Total above rivers and related areas	27,591	2,438	0
Caloosahatchee River and lower west coast	1,626	90	0
Lower east Coast and Everglades	6,833	43	0
Grand total of Florida	62,991	7,364	24

pressed in acres classified according to density, using the following terms:

(a) Sparse—more open water than hyacinth.
(b) Moderate—less open water than hyacinth.
(c) Dense—no open water but not compacted.
(d) Very dense—compacted.

Also shown are other classifications, such as accessibility to presently used mechanical equipment and waterway use.

The total area of hyacinths as computed from the survey in the State of Florida is 62,991 acres. Of this amount, 3,967 acres

were classified sparse; 21,934 acres moderate; 22,801 acres dense; and 14,289 acres very dense.

Among the more heavily infested waterways of the State are the Kissimmee, St. Johns, Withlacoochee, and Peace Rivers, with their tributaries. Hyacinths were found in 55 of 67 counties of Florida. Over one-half of the hyacinths in Florida were found in the following five counties: Polk, Okeechobee, Highlands, Palm Beach, and Volusia.

Of course, it will be appreciated that the area and location of hyacinths vary with the wind, floods, weather, and other factors, such as propagation. So the area, location, and density of hyacinths, if resurveyed today, would unquestionably differ somewhat from that made in 1946-47 or from a survey made say 2 years hence. It is believed the information obtained is accurate and adequate for use in the forthcoming report of the South Atlantic Division Committee scheduled for completion November 1, 1948.

In Figure 1 is to be found a very small scale reproduction of Map No. 8 as typical of the 9 required to cover the whole State for the purposes of this survey. Inasmuch as No. 8 covers the Kissimmee River from its upper reaches to Lake Okeechobee, it is about as typical as any of them and at the same time represents about as many hyacinths.

ALLIGATOR WEED—A NEW MENACE FOR FLORIDA

L. S. Evans*

Alligator weed, sometimes called alligator grass (*Alternanthera philoxoides*) (Mart.) or (*Achyranthes philoxeroides*) is a member of the Amaranth family closely related to pigweed. It is commonly found in ponds, ditches, bays, and sluggish streams where it forms floating mats over extensive areas crowding out other plants. Alligator weed is a native of Central and South America and according to Penfound it was discovered in the New Orleans area in 1898 by R. S. Cocks.

The plant usually becomes established in wet soil near the water's edge and then extends downward and out over the water by means of horizontal floating stems. Flowers are produced on vertical shoots growing from the prostrate stems. Since viable seed is not normally produced vegetative propagation is the principal means of spread. The roots when in water do not penetrate the soil, but do grow into the soil when washed ashore or otherwise grounded. If stems are broken mechanically, pieces as small as a single node can produce shoots and roots, thus establishing a new plant.

Distribution: Alligator weed is locally abundant in the lakes, bay and sluggish streams around Jacksonville and has been observed as far south in Florida as Ocala by the speaker. Localized infestations in the vicinity of Miami have been recently reported. This pest is also known to occur extensively in Louisiana, and to some extent in South Carolina, Georgia, Mississippi, Alabama, and Texas. The rapid spread indicates more effective methods of dispersal than the simple matter of vegetative reproductive segments drifting downstream. Lynch reports that alligator weed has already destroyed a vast acreage of valuable waterfowl and muskrat marshes, and is now threatening the salt-water fisheries of inner coastal waters of Louisiana.

He considers this plant a more serious threat to wildlife and fisheries than water hyacinth because it thrives on dry land and in fresh and brackish marches. Russell reports that where water hyacinth and alligator weed compete for dominance in shoal water, the latter is capable of excluding the former. When growing in association they form floating mats, the stage preparatory to development of flotant (floating marsh). In the half century since the introduction of these two species the flotant has developed at a revolutionary rate in Louisiana with the result that greater changes have occurred in the marshland than in the twenty centuries preceding, according to some authorities, and a large part of open waters have disappeared. The implications here are unmistakable.

*—Agronomist, Bur. Plant Industry, Soils and Agricultural Engineering, U. S. Dept. Agriculture, Beltsville, Md.

Control measures: Enough experimental work has been done with alligator weed to make it clear that control measures suitable for use against this plant in its terrestial habitat are not equally effective against it in its aquatic habitat. Arceneaux, et al, compared the effectiveness of flaming, hoeing, and 2,4-D in controlling this weed in sugar cane fields in Louisiana. The most

Figure 1.—Alligator weed, *Alternanthera philoxoides* (Mart.), one of our worst water weeds that usually makes its start on wet land adjacent, has been a common pest in Louisiana for many years. Its invasion of upper Florida waters is the proper concern of the present discussion. Note blossoms and free rooting at nodes of stems.

effective method was found to be 2, 4-D. Yields of cane were increased by 5 tons per acre in this case. The sprouts which regenerated following 2, 4-D were spindly and lacking in vigor. These plants were effectively suppressed by crop competition. No measurable effects on the cane resulted from 3 repeated sprayings with 2, 4-D aggregating $4\frac{1}{2}$ lb. of acid equivalent per acre. This is approximately twice the amount needed for satisfactory weed control. Complete eradication or even major decimation cannot, as a rule, be expected from a single application. From repeated spraying at appropriate intervals, progressive destruction of the underground system may be expected. From 3 to 5 weeks should elapse between applications of spray. High temperature and high level of vegetative activity are factors which tend to intensify the effect of 2, 4-D.

Applications of 2, 4-D to alligator weed growing in water will kill all emergent growth but regeneration occurs from the submerged stems with monotonous regularity within two weeks after treatment. Four applications of a dilute 2, 4-D spray made at 3 to 7 week intervals during the growing season greatly reduced the reserve food supply of the plant as judged by the vigor of recovering plants. It has not been determined how long such a treatment would have to be continued to bring about eventual eradication. In the absence of water level control, eradication of alligator weed with present herbicides will be difficult and expensive. Nevertheless, consideration should be given to a chemical measure in an effort to confine localized infestations in view of the potential serious threat which this plant presents.

Less is known about mechanical control measures but it has been reported from Louisiana that crusher boats used for hyacinth removal have been successfully used for removal of alligator weed. Effective removal of this plant by the use of the "saw-boat" or hyacinth cutter is not very promising because of the numerous reproductive fragments which would result from sectioning the stems. There is, in fact, reason to believe that the continued use of saw boats on alligator weed will be a material aid to the spread of the plant.

In the absence of more effective control measures alligator weed is a serious menace to the agricultural economy of southern Florida. The problem will be somewhat simplified by early recognition and treatment of localized infestations.

THE EFFECT OF AQUATIC WEEDS ON FLOW IN EVERGLADES CANALS*

DEAN B. BOGART**

DEAN B. BOGART

The major canals of the Everglades were designed carefully according to the knowledge and data available at the time and their construction represents a sizable capital investment. It is an unhappy but undeniable fact that the benefit of this capital investment has been only partly realized for long periods of time because of the effect of aquatic weeds on the efficiency of the canals. Thus the care of the designers was nullified in considerable measure by their inability to allow for a factor that developed later. In fact, they could not allow for the factor because it has no dimensions in the ordinary sense and the defect of omission cannot be held against them. The problem was more one of maintenance.

There are many aquatic weeds, and many weeds that tolerate much moisture, but those discussed here are the common ones known as water hyacinth, coon-tail moss, nigger-wool, and Para grass. Many other aquatic weeds exist in the Everglades but it will take someone like Mr. Erdman West to identify and name them for you, which he has done on pages 15-20 of this volume.

Hyacinth Jams

The water hyacinth has been the most widespread weed in

*—This paper was to have been presented by both Mr. B. S. Clayton and the writer. Shortly before the 9th Annual Meeting of the Soil Science Society of Florida, Mr. Clayton, Drainage Engineer for U. S. Soil Conservation Service at Belle Glade, Florida, was assigned to special duty in Washington, D. C., and could not attend the meeting. He organized the joint investigation of friction effect of hyacinth cover on canals by the U.S. Geological Survey and the U. S. Soil Conservation Service. With Mr. Edward King, he performed part of the field work on the slope-area reach of North New River Canal and all of the field work on Cross Canal. The computations of the friction coefficients were made by Mr. Clayton.

**—Hydraulic Engineer in charge of surface-water investigations in Southeastern Florida, U.S. Geological Survey, Miami. Transferred to Albany, N. Y., in June 1949. Published with the approval of the Director of the U.S. Geological Survey.

the canals. This prolific plant, with its remarkably beautiful flower, has been the cause of much grief, and many thousands of dollars have been spent on trying to control it or even to just get by with the problems it presents.

You will notice that I have used the form "has been" several times in the previous paragraph, as though the hyacinth problem were a thing of the past. It has not been eliminated as yet, but JOHNSON[1] has shown that it can be controlled in the Everglades. This simple statement, however, belies the magnitude of the work that made it possible to see the water surface of the canals again.

Probably the most obvious effects of the hyacinth on canals are the jams that occur at bridges and water-control structures. Hyacinths, either singly or in groups, often move with the current or are propelled by the wind and lodge very easily on any obstruction they may encounter. Despite their apparently frail structure, these succulent plants can make a surprisingly firm mass that requires considerable effort and ingenuity to remove. The stability of hyacinth jams is such that men can walk on them without fear of breaking through, as shown in Figures 1 and 2. When a jam has begun to accumulate on an obstruction, the current forces arriving plants against the edge of the jam and rolls some of them underneath the jam where the stems, leaves, and roots interlace and, in effect weave a solid mass. The development of a hyacinth jam then is a combination of accretion in area and a rolling-under action that increases the vertical dimensions of the mass.

Where the jam may have a semi-detached status, buoyancy of the plants may cause the mass to build up as much as 10 feet above the surface of the water, as in Figure 1. If such a jam is loose enough, the pile of plants may resemble a volcano, with plants rising slowly through the center of the mass and rolling down the slope. Some of the plants may even be rolled under again, thus establishing a cycle of movement. This kind of jam does not occur very often.

The more-common type of hyacinth jam is shown in Figure 2. Here the plants accumulated on bridge piers, but, instead of building up, the jam built down and horizontally. Thus a mass of plants about 6 feet deep developed out from the piers and ultimately extended from bank to bank of the canal. The jam was laboriously cut into rafts of weed by using 6-foot timber or ice saws. It is expensive to remove such jams and in the aggregate they have cost the Everglades area many thousands of dollars directly, not to mention the less obvious costs of lost canal efficiency. Dynamite has been used to break up some jams, but this heroic measure is seldom employed.

A unique block occurred in the West Palm Beach Canal in which hyacinths jammed both high and deep. In this case it was necessary to hack trenches about 4 feet to the water surface and then cut below that with the 6-foot saws.

Figure 1.—Mass of hyacinths caught on shoal just below control and lock in West Palm Beach Canal at U. S. Highway 1; action of fast-moving water piled the growth more than 10 feet higher than the water surface.

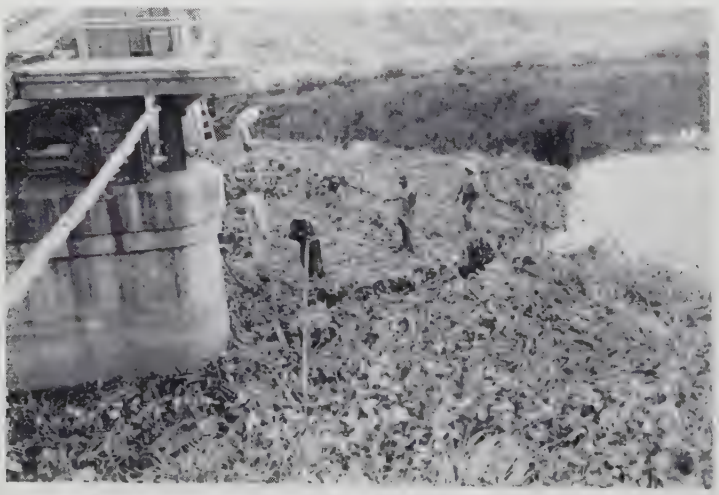

Figure 2.—Jam at F.E.C. Railway bridge at West Palm Beach, Florida. Workers have cut large section loose with 6-foot timber saws and are starting to move it through bridge. When jam moves freely, workers run for ladder which is lashed to the farther pier.

The building of bridges with a number of short spans caused many hyacinth jams to form in the narrow channel openings of the bridges. This resulted in the establishment of a set of regulations [EVERGLADES DRAINAGE DISTRICT,'] that require a principal clear span of 29 feet in any bridge across a major canal.

Little research has been done on the blocking effect on canals caused by hyacinth jams, but as much as a 2-foot backwater effect* has been observed at controls in the Everglades canals. It has been reported that flow in lateral canals can be stopped entirely by hyacinth jams.

The Equations of Flow

The flow of water in any channel (or conduit) is expressed by the basic equation:

$$Q = av \qquad (1)$$

where Q = the rate of flow, in terms based upon the unit in which a and v are expressed; it is usually in cubic feet per second (c.f.s.).

a = the area of the channel, in cross-section.

v = the mean velocity of the water in the section.

As a can be measured or designed quite easily, the equation appears simple, as indeed it is for certain purposes. The factor v can be measured in existing channels, but when it comes to computing v, complications arise. The velocity of flow in an open channel can be expressed in the fairly simple equation known as the Manning formula, which probably is the most used of flow equations:

$$v = \frac{1.486\ r^{2/3}\ s^{1/2}}{n} \qquad (2)$$

The Manning formula is combined with equation (1) to arrange all the factors of flow in one question when the volume of flow is the answer sought:

$$Q = \frac{1.486\ ar^{2/3}\ s^{1/2}}{n} \qquad (3)$$

The volume of flow in an open channel, then, can be expressed by four interdependent variables which are used in all of the best known equations:

1. Area (a).—Discharge of a channel obviously varies directly with the cross-sectional area—the larger the channel, the greater the discharge, and so on.
2. Hydraulic Radius (r).—Although the discharge of a channel varies directly with the area, the proportions of the channel have an effect on the volume of discharge. For channels with

*—Backwater effect is a measure of the rise in the level of a canal or stream caused by an obstruction; it resembles the reaction of a waterway to a submerged dam.

a cross-sectional area, say, of 1,000 square feet, it is obvious that a channel 100 feet wide and 10 feet deep is more efficient (from several viewpoints) than a channel 500 feet wide and 2 feet deep. The contact of moving water with the sides and bottom of a channel causes a certain amount of turbulence and friction loss; and the greater the area of contact, the greater will be the friction loss. This feature of the proportions of a channel is taken care of by a factor known as the hydraulic radius, which is the ratio of the cross-sectional area of the channel to the wetted perimeter of the channel. The wetted perimeter is that portion of the perimeter of the cross section where the water and the ground material are in contact. As shown in equation (3) the discharge varies as the two-thirds power of the hydraulic radius.

3. Slope (s).—The slope of the water surface of a channel also affects the discharge—the steeper the slope, the greater the discharge, and conversely. The slope is measured in a vertical plane parallel with the current. The discharge of a channel varies as the square root of the slope, rather than directly with the slope.

4. Friction Factor (n).— The flow of water in a channel is a function of the quality of the surfaces of that channel; that is, the relative smoothness or roughness of the channel. A smooth concrete flume surely will carry more water than a brushy or stony channel of the same dimensions. This problem is met by the inclusion of a coefficient of roughness, or friction factor, which appears in the denominator of the Manning formula. By the mathematics of the equation the greater the value of n, the less will be the amount of discharge, other factors being the same. Therefore, the value of n increases with the roughness and turbulence-producing features of channels.

The assigning of a value of n for an existing or a proposed channel is one of the more difficult problems of hydraulics. It is an empirical factor, evaluation of which has been obtained from numerous measurements of flow covering a wide range of channel conditions. Because the value of n has a fairly narrow range for ordinary channels, a difference of a few points in selecting the value means a sizable difference in the discharge being computed. Typical values of n that were assembled by HORTON[2] are listed in Table 1. These values are not fixed, but the tabulation is highly useful as a reference base for general design and computation purposes. The selection of a proper value of n is one of those things that are a matter of experience.

Another part of the friction loss in open-channel flow is that caused by contact of the air with the surface water. This friction loss is definite but for most purposes it is so small that no attempt is made to evaluate it. The easiest way to appreciate that air-water friction is real is to observe the develop-

TABLE 1.—Values of n for Use in the Kutter and Manning Formulas; Prepared by R. E. Horton.[2]

Channel characteristics	Best	Good	Fair	Bad
Canals and Ditches:				
Earth, straight and uniform	0.017	0.020	0.0225	0.025
Rock cuts, smooth and uniform	.025	.030	.033	.035
Rock cuts, jagged and irregular	.035	.040	.045	
Winding sluggish canals	.0225	.025	.0275	.030
Dredged earth channels	.025	.0275	.030	.033
Canals with rough stony beds, weeds on earth banks	.025	.030	.035	.040
Earth bottom, rubble sides	.028	.030	.033	.035
Natural Stream Channels:				
(1) Clean, straight bank, full stage, no rifts or deep pools	.025	.0275	.030	.033
(2) Same as (1), but some weeds and stones	.030	.033	.035	.040
(3) Winding, some pools and shoals, clean	.033	.035	.040	.045
(4) Same as (3), lower stages, more ineffective slope and sections	.040	.045	.050	.055
(5) Same as (3), some weeds and stones	.035	.040	.045	.050
(6) Same as (4), stony sections	.045	.050	.055	.060
(7) Sluggish river reaches, rather weedy or with deep pools	.050	.060	.070	.080
(8) Very weedy reaches	.075	.100	.125	.150

ment of wave action and to consider the magnitude of the forces involved.

The discharge of a channel is expressed by equations other than the Manning formula. The oldest of these, and an apparently simple one, is the Chezy formula:

$$v = C\sqrt{rs} \qquad (4)$$

The terms r and s are the same as described in the preceding section. The term c corresponds in part to the n in the Manning formula but is of a different magnitude.

The selection of c in the Chezy formula was made more positive by the development of the Kutter formula:

$$c = \frac{41.65 + \frac{0.00281}{s} + \frac{1.811}{n}}{1 + \frac{n}{\sqrt{r}}\left(41.65 + \frac{0.00281}{s}\right)} \qquad (5)$$

You will note the Kutter formula incorporates the same factors that were used in the other equations noted in this paper. It is a somewhat cumbersome equation which gives a roughness coefficient (c) by introducing a second roughness coefficient (n).

The Manning formula originally was developed also to provide the value of c in the Chezy formula, but because of its con-

venience it is usually written in the form of equation (3). Both the Kutter and the Manning formulas give comparable results if the person who selects the values of n is accustomed to working both formulas. Most investigators, however, work with one or the other of the formulas, and, owing to its simplicity, the Manning formula probaly is the most used.

Weed Effect On Discharge

The several equations noted in the preceding section are arranged for computing v or Q. In this paper, the equations have been used to compute c and n, which are measures of the roughness and the efficiency of channels. Although values of c are tabulated, the principal discussions are concerned with the value of n, as used in the Manning formula.

As n is a direct mathematical factor in the equation of flow, the ratio of two values of n can be considered a measure of efficiency:

for a clean channel, $n = .032$
for same channel, weedy $n = .060$
efficiency of channel $= .032 \times \frac{100}{.060} = 53$ per cent

This is, for the same hydraulic radius and the same slope, the water-carrying capacity of the channel was reduced to 53 per cent by the weed condition (hypothetical).

In an ordinary channel, the water surface of which is clear, the flow of water near the banks and bottom is subject to turbulence, in degree according to the roughness of the banks and bottom. The amount of turbulence varies not only with the roughness, but for a given roughness, varies also with the velocity. As velocities approach zero, the turbulence will be very small and relatively unimportant. With water flowing at high velocities, the turbulence may be very large, and the friction loss, therefore, may be considerable.

The principal part of the water hyacinth is above the surface of the water, owing to the buoyancy of the plant. The fern-like roots, however, extend as much as twelve to eighteen inches beneath the surface of the water, as shown in Figure 7. When a canal is completely covered with hyacinths, thousands of roots hanging beneath the plants may occupy the canal to an average depth of say 1 foot. This is a reduction of the cross section of the canal, and in a canal 10 feet deep would cause a reduction in area of 10 per cent, which is demonstrated by the position of a in the Manning formula, equation (3). A lateral canal only 5 feet deep would have a reduction in area of 20 per cent and an indicated reduction in efficiency to 80 per cent. Thus, it can be seen that the simple reduction in channel area may be a very important factor in the efficiency of canals, a factor that increases in importance as the size of the canal decreases.

The reduction of cross-sectional area is not the principal problem caused by hyacinth cover in a canal. The roots of hyacinths, tender and fragile though they may be, have an effect that is the same as that caused by rough sides and bottoms of canals. The roots cause a surprisingly large amount of friction loss by inducing turbulence in the water. With complete hyacinth cover, a canal becomes in effect a closed conduit and there is no free water surface—see Figures 3 and 7. Although the mat of plants

Figure 3.—Complete cover of mature hyacinth on North New River Canal at South Bay, Florida. View is downstream along centerline of canal. Wilted plants in foreground were sprayed with 2, 4-D two days before photograph was taken.

can rise and fall with changes in water level, it continues to restrict flow, whatever the depth of water.

On a large canal the reduction of efficiency is as great as 50 per cent. This means that unless the canal is maintained clear of hyacinths, about one-half of the capital investment of the canal is not realized. Consider the state of the canals in the Everglades for a period of years prior to 1947, and you will realize what a lot of money was wasted because of the inability to cope with the hyacinth problem.

Hyacinths are not the only aquatic weed that reduces the flow in the Everglades canals—see the line-up of obnoxious weeds on page 23 in this volume. The term "nigger-wool" (a *naiad?*) is used in the Everglades to designate a wide variety of bottom-rooted weeds, the scientific names of which the writer does not know and, therefore, nigger-wool will be used here for the sake of simplicity. These bottom-rooted weeds usually exist only in the absence of hyacinths. Apparently they need the sunshine that a hyacinth cover intercepts. They are wonderful plants which in their way are just as prolific as hyacinths, attaining

lengths as great as 25 feet and rising in graceful arcs to the surface of the water. In mass they constitute a very offective barrier to flow, such that a major canal might have an indicated efficiency of only 10 per cent. These bottom-rooted weeds, therefore, can outdo hyacinths as a pest. Some extreme examples of this condition are shown in Figures 5 and 6.

Nigger-wool also forms serious jams at bridges and control

Figure 4.—A sizable canal in period of extreme drought, with a variety of aquatic weeds and water-tolerant weeds essentially blocking all flow. View is to south along Krome Avenue Canal from the Tamiami Trail, at a point 17 miles west of Miami.

structures. In rainy periods as the water in a weedy canal rises, a certain amount of flow occurs which gradually overcomes the weed by making it lie flatter and depressing it toward the bottom of the canal. Flow then occurs only in the upper part of the cross section, and as the velocity of flow increases, the plants tend to break up and move downstream. It is probable that the roots remain in place, however, unless the bottom of the canal scours in considerable degree, and the stage is thus set for a regrowth of the plants. Experience in the field indicates the possibility that plants of this nature tend to break up not only from the action of moving water but also from the reduction of air temperature in the fall of the year. The writer does not know if any research has been done along these lines, and points out the difficulty involved in such research because the higher velocities in the canals often occur at the time when the weather becomes cooler.

When nigger-wool breaks up, whatever the cause, it moves downstream and often collects in large masses. These collections become as large as 20 feet in diameter, and, because the plants have nearly the same density as water, the masses may be sev-

eral feet thick. Under certain conditions, apparently when the plants have lost their small amount of buoyancy, clumps of weeds are submerged and move downstream with none showing at the surface.

Like hyacinths, the detached nigger-wool forms jams at bridges and water control structures. While the jams ordinarily are not as extensive as the larger hyacinth jams, they may cause

Figure 5.—Efficiency of canal reduced to about 10 percent by long streamers of weed; view east along Tamiami Canal near Miami city limits.

just as much restriction to flow. The plants are soft but tend to pack hard against obstructions and have to be cut away with long-handled choppers.

The possibilities of damage from weed jams are well demonstrated in a report by JOHNSON,[3]. Aquatic weeds started breaking loose in one of the larger canals of Lake Worth Drainage District. A mass of the growth accumulated and continued to increase in size by a rolling action similar to that of a snowball. The large mass of weeds lodged on an obstruction (apparently a bridge or water control) and completely clogged the canal. As head developed on the plug thus formed, water by-passed the plug and a washout developed. This continued until the washout was about half the size of the canal section and head loss at the constriction was reduced to a negligible amount. The event occurred in a region of deep sand, but a similar washout could occur in areas of other soils.

In drought periods, a variety of water-tolerant plants tend to establish themselves in shallow canals, as shown in Plate 2-B. Most of these plants do not thrive in deep water but for long periods they can make the efficiency of a canal very low and even stop flow altogether.

Not shown in any of the illustrations of this paper, but appearing on page 17 of the paper by West is Para grass. This luxuriant plant is what Mr. West calls a *banker*. It roots on the banks of a canal but tends to grow out through and on the water and may cause a serious reduction in canal capacity. This pest (as far as canals are concerned) has caused trouble in ditches and laterals for many years, but only recently has it affected the

Figure 6.—A major canal in which discharge capacity is greatly reduced by heavy growth of bottom rooted weeds; view of Miami Canal at Pennsuco. The small amount of hyacinths shown is a rarity in the lower Miami Canal and is the most seen in 7 years of intensive inspection along the canal.

larger canals. In the spring of 1949, Para grass had encroached on Hillsboro Canal at Belle Glade from both banks (As shown in the photo cited above) and the visible surface of this 70-foot wide canal was reduced to a narrow lane about 20 feet across. Just what was occurring beneath the surface was not determined, but it is likely that the efficiency of the canal was less than 50 per cent.

Other crawling bankers tend to move out on and through hyacinth cover on a canal, and, by weaving themselves through the hyacinth plants, help develop a mat of weed that is extremely hard to break up. The writer has seen this condition at numerous locations in the Everglades but the outstanding example of this sort was where pigweed 10 feet high was growing on top of the hyacinth and intertwined bankers. One other example of extreme weed condition comes to mind, when some enterprising citizen had beaten the weed growth down to a flat surface, where mixed with muck, it had formed what was practically a soil. There, on top of about 8 feet of water, this person had planted a

seed bed and garden. Needless to say, a jam of this stability is very hard to destroy.

North New River Canal

In 1942, Mr. B. S. Clayton laid out a half-mile slope course on North New River Canal at the Palm Beach-Broward county line. At that time there was only a narrow fringe of hyacinth plants along the banks of the canal and there was evidence that, without any maintenance, the canal would be covered with hyacinths within a year or two. Discharge was measured with a variety of water conditions by engineers of the U. S. Geological Survey and the water slope was measured at the time of each discharge measurement. Additional observations were made as the fringe of hyacinths increased and ultimately the surface became entirely covered, making it necessary to hack an opening across the canal in order to make the observations. One of the difficulties in doing this kind of work in the Everglades is the flat water slope usually encountered. Despite this limitation, the computations show a gratifying degree of consistency.

Some of the basic data from the discharge measurements and the roughness coefficients computed from the data are shown in table 2. Coefficients were computed using all three of the principal discharge formulas—Chezy, Kutter, and Manning. It will be noted that the values of n increased as the amount of hyacinth cover increased, to a point where the efficiency of the canal was only about 40 per cent of the efficiency when the surface was free of hyacinths. Although values of n often are used interchangeably in the Kutter and Manning formulas, the results of these observations show a significant difference between the values of n computed by the two formulas using the same base data.

Referring to Table 2, the $n = 0.022$ (Manning) for the observations on May 22, 1942, shows that the reach selected for the study was in surprisingly good condition. The writer believes that $n = 0.030$ or $n = 0.035$ is generally used for designing large canals in the Everglades. It is interesting to note the increase in the value of n as the fringe of hyacinth developed along the banks. The $n=0.033$ on June 13, 1942, may be larger because of the increase in velocity, but it is believed that most of the increase can be attributed to the encroaching hyacinth mat. The observations made in 1943 and 1944, when North New River Canal was completely covered with hyacinths, show the notable increase that occurred in the roughness coefficient. The value of n ranged between 0.048 and 0.069 and a fair average would be 0.055, although this would in part depend upon the depth and velocity of the water. Thus, n increased 2.5 times, and the reciprocal of this change, 0.40, or 40 per cent, is a measure of the water-carrying capacity of the canal.

TABLE 2.—Computation of Roughness Coefficients for Slope Course On New River Canal in the Florida Everglades

Date	Average maximum depth feet	Average width feet	Discharge c.f.s.	Average cross-section sq. ft.	Mean velocity ft./sec.	Mean hydraulic radius feet	Slope of water surface ft./ft.	Chezy C	Kutter n	Manning n
1942										
May 22[1]	8.7	66.5	238	435	0.547	6.16	0.000006	90.0	0.026	0.022
June 2[2]	9.5	68.4	344	491	.700	6.70	.000010	85.6	.028	.024
13[3]	14.0	77.8	877	829	1.058	9.33	.000028	65.4	.040	.033
1943		With dense growth of hyacinth from bank to bank								
June 17	9.2	67.9	121	474	.255	6.56	.000006	40.7	.062	.050
Aug. 12	9.8	70.3	208	515	.404	6.86	.000017	37.4	.066	.055
Sept. 30	9.6	69.9	210	500	.420	6.78	.000019	37.0	.067	.055
Nov. 9	11.8	77.8	172	665	.259	7.86	.000007	34.8	.078	.060
1944										
Jan. 17	11.8	77.8	190	618	.308	7.31	.000007	43.0	.061	.048
May 1	9.0	67.0	181	456	.397	6.42	.000029	29.2		.069

[1] Hyacinth and grass extended 2 feet out from both banks.
[2] Hyacinth and grass extended 4 feet out from both banks.
[3] Hyacinth and grass extended 6 feet out from both banks.

TABLE 3.—Computations of Roughness Coefficients for Slope Course On Cross Canal in the Florida Everglades

Date	Average maximum depth feet	Average width feet	Discharge c.f.s.	Average cross-section sq. ft.	Mean velocity ft./sec.	Mean hydraulic radius feet	Slope of water surface ft./ft.	Chezy C	Kutter n	Manning n
1940			Narrow fringe of grass and hyacinth at banks							
Apr. 4	11.7	61.2	220	513	0.429	7.52	0.000013	43.5	0.060	0.048
Apr. 26	10.5	59.5	256	444	.577	6.77	.000021	48.5	.050	.042
Aug. 8	11.1	60.0	222	477	.465	7.14	.000015	45.0	.056	.046
1941			With dense growth of hyacinth from bank to bank							
Mar. 28	12.1	62.0	159	539	.295	7.76	.000020	23.6	.118	.089
Apr. 25	11.3	60.5	177	485	.365	7.20	.000027	26.2	.097	.080
May 13	11.8	61.4	148	522	.284	7.60	.000018	24.3	.109	.086
May 15	11.6	61.0	152	506	.300	7.45	.000020	24.6	.106	.086
May 16	11.3	60.5	144	486	.296	7.21	.000021	24.0	.107	.086
Dec. 24	10.6	59.6	177	447	.396	6.80	.000038	24.6	.100	.084
1942										
Jan. 5	10.6	59.6	171	447	.382	6.80	.000038	23.8	.104	.087
Jan. 20	10.6	59.7	166	450	.369	6.83	.000038	22.9	.108	.090
Feb. 3	10.1	58.5	128	415	.308	6.46	.000030	22.1	.110	.092

Cross Canal

Another study was made (entirely by Mr. Clayton) on Cross Canal near the Haney and Wedgeworth farms in 1940-42. Cross Canal is smaller than North New River Canal and apparently was not in as good condition as the larger canal. This is shown in table 3 where the value of n averaged 0.045, with no hyacinth cover, which is just about twice the value of n for North New River Canal when clear and indicates a considerable degree of roughness or unevenness in the sides and bottom of Cross Canal. When the canal was new, n probably was somewhat lower.

The second part of table 3 shows conditions in Cross Canal with a dense growth of hyacinths on the surface. The value of n ranged from 0.080 to 0.092, and averaged 0.086. This indicates a reduction of efficiency to 52 per cent and again demonstrates in what large degree hyacinth cover can affect a canal. It is unfortunate that the observations were taken when the range of discharge was relatively small. However, recalling the condition of Cross Canal at that time, it is probable that not much more than the maximum flow observed (177 c.f.s.) could have occurred in the canal.

Miami Canal

For some unknown reason, and this itself might make an interesting study, hyacinths were not a problem on lower Miami Canal in the period of observations by the U. S. Geological Survey. As shown in plate 3-B, the only hyacinths ever seen were a few small colonies which did not develop into the complete cover that infested the other major canals of the Everglades. However, from the junction of South New River Canal to the edge of the city of Miami the canal was host to a number of prolific bottom-rooted weeds. The most extensive one of these weeds has been identified to the writer by Mr. West as a *naiad*—see page 23 in this volume. Whatever its identity, the weed found conditions to its liking and usually had an annual period of growth that for long reaches filled Miami Canal from bank to bank and from top to bottom. As shown in Figure 5 it also occurred in Tamiami Canal (in many other canals, too).

This *naiad,* by forcing the water to follow a tortuous path around thousands of stems and leaves, reduced the efficiency of Miami Canal in amazing degree. No specific studies were made to determine the loss of efficiency, but useful information may be gleaned from the stream records maintained on the canal since 1939. Some comparative figures for selected dates are shown in Table 4, which illustrates the weed problem in terms of stage, slope, and discharge rather than from the standpoint of the roughness coefficient.

The data were selected on the basis of a nearly constant drop

(or fall) between the water-stage gages at Pennsuco and at the water plant in Hialeah—in this case ranging between 2.5 and 2.8 feet. As an additional basis for correlation, the stages for the two recording stations also are listed.

TABLE 4.—Stage, Slope, and Discharge of Miami Canal on Selected Dates

Date	Mean stage,* in feet, m.s.l. datum		Fall, in feet Pennsuco to Water plant	Discharge in c.f.s. at Water plant
	Pennsuco	Water plant, Hialeah		
1944				
May 14	3.9	1.4	2.5	500
June 16	3.2	.7	2.5	150
July 2	2.9	.4	2.5	80
Oct. 3	4.4	1.6	2.8	340
Nov. 23	4.4	1.8	2.6	700
1946				
Sept. 8	4.6	2.0	2.6	900

* Mean stage is used because canal was affected by tidal backwater.

The series of five dates in 1944, in Table 4, show nearly a cycle covering the extreme weed situation of that year. On May 14 the flow was 500 sec.-ft. and the reach of canal was infested with weed. By July 2, with the same amount of slope, the discharge had decreased to 80 sec.-ft.—an indicated efficiency of 16 per cent, based on the May 14 data. Discharge increased in the fall of the year and on October 3 was 340 sec.-ft. and on November 23 was 700 sec.-ft., with slope conditions nearly the same on both dates. The increasing discharge shows that the weeds were pretty well beaten down or broken off by the November observation.

If the July 2 and November 23 data are compared, the July 2 condition shows an indicated efficiency of about 11 per cent, which is certainly worse than anything experienced with hyacinth cover in the larger canals. Similar data for September 8, 1946, are included in Table 4 to show that a discharge of 900 sec.-ft. occurred with the same drop between the two observation stations.

Based on these data, it is safe to suggest that efficiency of a canal may be reduced to only 10 per cent when one of the *naiads* and other bottom-rooted weeds take over. In looking at Table 4, the reader may point out that the data are not entirely consistent in that the stages shown for Pennsuco and Hialeah are not the same for the several dates noted even though the amount of drop is essentially the same. This defect is admitted, but it may be argued that the approximately 1.5-foot range of stage in the 1944 series of readings does not nearly account for the variation

in discharge. The problem was one of magnitude and the condition reported does not necessarily represent the worst condition that obtained in 1944.

It may be interesting to note that an attempt was made to cut weed growth of this nature in Miami Canal. In 1944 at the height of the dry season the salt intrusion situation in lower Miami Canal was such that the principal municipal water supply (at Miami Springs) was in serious danger of contamination by salt water that had advanced up Miami Canal to near the well field area. Emergency measures were taken by the city of Miami to protect the water supply and to augment flow of fresh water toward the well field. As part of these measures, the thick weed growth was cut in a 2.5-mile reach of Miami Canal southeast of Pennsuco. A double-edged saw, very narrow and flexible, but 90 ft long, was moved along the canal in a sawing motion and about 50 per cent of the cross-section was freed of weeds. Undoubtedly more water was able to move downstream because of this work, but the over-all success of the project could not be determined because rainfall complicated the observations.

CONCLUSIONS

It has been shown that where a large canal is covered with hyacinths the efficiency of the canal as a water carrier may be reduced to 40 per cent. This means that the capital investment likewise may be only 40 per cent effective and may in part explain the cause of some of the financial difficulties of the Everglades area in the period 1930-45. Thus, more benefit per dollar spent on maintenance can be and has been realized by removing the hyacinth cover on the canals than in any other way possible. Even though the canals never were finished according to the original design, the improvement afforded is worth many times the cost involved. Rarely, in engineering, is it possible to achieve a relative increase in efficiency of any facility from 50 to 100 per cent (based on original conditions) for a maintenance cost say of only part of 1 per cent of the capital investment, JOHNSON.[4]

Up to recently, the difficulties of hyacinth cover and weed growth were appreciated by those who operated the canal system of the Everglades, but even they did not know the real magnitude of the problems involved. In recent years, work similar to that reported here has provided an evaluation of some of these problems and also has provided a sound working basis for improvement. Unfortunately, some of the most pertinent studies have been made secondary to the general water problems of the Everglades, but enough information has been obtained so that definite designing and planning can again be undertaken, this time with a much greater degree of confidence. Any reader who has studied intensively the data in Tables 2 and 3 may have

TABLE 5.—Computation of Discharge With Equivalent Conditions; North New River Canal in the Florida Everglades

Date	Average maximum depth	Average width	Discharge	Average cross-section	Mean velocity	Mean hydraulic radius	Slope of water surface	Chezy C	Kutter n	Manning n
1947	feet	feet	c.f.s.	sq. ft.	ft./sec.	feet	ft./ft.			
July 23[1]	13.40	77.8	1050	788	1.33	9.50	0.000042	66.5	0.038	0.032
No. 1[2]	13.40	77.8	622	788	.789	9.50	.000042	----	----	.055
No. 2[3]	15.40	77.8	840	944	.89	11.36	.000042	----	----	.055
No. 3[4]	17.40	77.8	1080	1099	.984	13.24	.000042	----	----	.055

[1]As measured; no hyacinth cover
[2]Same stage; with hyacinth cover
[3]Stage 2 feet higher; with hyacinth cover
[4]Stage 4 feet higher; with hyacinth cover

wondered why the loss of efficiency in North New River Canal with hyacinth cover was greater than the loss in Cross Canal; particularly, as North New River Canal is the larger and should have been affected less by the cover. Based on his experience on these two canals the writer can give no positive answer, except to point out that Cross Canal has been a very poor carrier

Figure 7.—Portrait of a hyacinth plant and one of its "Offsprings." The small plant at the right is from a stem that has emerged from the crown of the larger plant. This is thought to be its principal means of propagation. Note also the long root mass that is only partly shown that normally is suspended, full length, in the water and is the cause of so much loss of flow in a channel which has its surface covered by such a growth.

of water and apparently contains obstructions or a large measure of roughness that does not occur in North New River Canal. This is shown by the higher value of n for both clear and hyacinth cover conditions in Cross Canal. It also suggests that hyacinth cover was not the only weed condition that reduced flow in Cross Canal.

Mr. Clayton made some further computations which are listed in Table 5. In July 1947, when the great Everglades flood was developing, the writer made a discharge measurement of North New River Canal at the slope reach. The actual observations are noted in Table 5 and from them $n = 0.032$ was computed. The discharge was relatively high and there was no hyacinth cover. As item No. 1, Mr. Clayton has taken the same information and computed the discharge using $n = 0.055$ as obtained when there was hyacinth cover on the canal. This shows a decrease of discharge from 1,050 to 620 sec.-ft., a reduction of about 40 per cent. It was fortunate for the Everglades that the hyacinth cover on the major canals had largely been removed by the time of the great flood. The writer does not mean to imply that the hyacinth mat was a deciding factor in the severity of the flood, but he does believe that the period of flood conditions was sensibly shortened because the hyacinths had been removed.

As items Nos. 2 and 3 in Table 5, Mr. Clayton increased the stage, that is, the depth of the water by two-foot increments and figured the resulting discharge using the same slope of the water surface. These computations show that with the canal covered with hyacinths, it would have been necessary to have four more feet of water to produce the same amount of flow that occurred on July 23, 1947, when the canal was clear. This information has been included in the paper to provide a means of making comparisons between discharge with and without hyacinth cover.

Based on the information presented about the effect of the bottom-rooted weeds on flow, the writer is wondering if hyacinths are the chief pest among the aquatic weeds—and this question is shared by a number of others who work with the canals. It has been observed that where hyacinths do not exist or where they have been removed, the bottom-rooted weeds tend to move in with resultant loss in canal efficiency. Although this may be a slow process in the major canals in the Everglades, now that the hyacinth problem has been brought under control, there is reason to believe that the other weeds will have to be considered. The writer does not suggest that possibly hyacinths should be encouraged to grow again as the least of several evils, but he does recommend that serious attention be given to the possibilities of the situation. By the time this paper is published, it may well be that the means for destroying nigger-wool, the naiads, and Para grass will have been developed. From the progress of the last several years, it seems that this should come about. How-

ever, the tenacity of the naiads and the rapidly increasing growth of Para grass indicate that the weed problems of the Everglades are by no means over.

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THE RELATIONSHIP OF WATER WEEDS TO NAVIGATION

W. Terry Gibson*

This most difficult and, at times, vexing problem was discussed by Mr. Gibson with the knowledge and understanding of one who has had a considerable amount of personal contact with it; also with a restraint born of the circumstances attending the Symposium whereas the vocabulary of a tugboat captain doubtless would have afforded a much more direct incision to the subject, all circumstances considered.

Inasmuch as Mr. Gibson did not provide a formal manuscript to cover the subject of his discussion, the general setting of the relationship is well illustrated and, indeed, may be all but sufficiently set forth by Figure 1 which is helpfully offered—a hyacinth eradicating boat that does not seem to be too sure of what is happening or of what is going to happen. Naturally the difficulties occur whether the weeds involved are what Mr. West has so aptly classified as "Floaters," "Bankers" or "Sinkers" or mixtures thereof.

In any event, Mr. Gibson pointed out that it required no great feat of the imagination to picture the heroic struggles Everglades pioneers must have been subjected to in fighting their way through such obstacles when the waterways were the principal avenues of ingress and egress to the lake region whether for moving ordinary supplies, heavy equipment such as draglines and large barges or merely themselves.

While Mr. Gibson placed great importance throughout his discussion on the development of water transportation in such an area as South Florida by pointing out that "Boats for pleasure as well as other uses bring revenue to the area" he also emphasized there should be no public fear of over-emphasis of navigation from the Federal standpoint as just another feature of government control such as seems to be entering the minds of some people. He also very strongly urged that more and more attention be given to the coordination of soil and water conservation planning and operations into a strong, carefully integrated system of development in which all elements are known to be so highly compatible if properly developed and understandingly brought together.

—Editor.

*—Attorney, West Palm Beach and Ranchman, Bean City, Fla.

Figure 1.—An early hyacinth-eradicating appliance operating in the upper reaches of the Miami canal in 1940 rather well illustrates the problem of waterbourne craft in those days; also the impossibility of eradicating this rapidly growing pest be mechanical means of this nature. The upper view of the machine shows it "Going" and the lower one "Coming."

HYACINTH HAZARD TO AMPHIBIOUS AIRCRAFT AND SEAPLANES IN THE STATE OF FLORIDA*

WILLIAM C. LAZARUS**

Florida's 58,666 square miles of area is so interspersed with fresh water lakes, rivers, and protected coastal waters as to make it ideally suited for safe operation of amphibious aircraft and seaplanes. Any lake or body of water 2500 feet in length is a potential seaplane landing area. 1000 feet of water provides a safe emergency landing area for such aircraft when in trouble. Therefore, nearly every body of water in the state is a potential safe landing area for amphibious or float equipped aircraft.

Obstructions such as water hyacinths on the surface of the water are extremely hazardous to the landing of such aircraft. These aircraft in general have relatively high centers of gravity necessary for keeping the propellers well away from the water for proper operation. Any amphibious aircraft or float equipped aircraft weighing less than 5,000 would be completely wrecked with probably loss of life if it were to come in contact with a floating mass of hyacinths three feet or more in diameter. Landing on waters completely covered with hyacinths would be certain death to the occupants of the plane as immediately upon contact the plane would be nosed over.

It therefore appears obvious that the safety of flying can be greatly enhanced by the eradication of haycinths from the waters of lakes and canals in the State of Florida.

The following specific examples are cited to support this claim:

A Luscombe airplane being flown from Miami, Florida to the West Coast of Florida was following the Tamiami Trail across the Everglades. It's altitude was 500 feet when it encountered engine failure. The canal along this highway was fortunately free of hyacinths at this point and the airplane being equipped with floats was able to land safely in the canal. If hyacinths had been present at this point it is probable that the occupants would have been killed, or at least an aircraft worth approximately $4,000 would have been totally lost.

There are approximately 600 miles of canals in the Everglades area alone similar to the one paralleling the Tamiami Trail. Every foot of these is a potential safe landing area for aircraft. Aircraft equipped with floats or hulls now religiously avoid areas where the waterways are congested with hyacinths. A truly safe direct line flight from Miami to the Tampa area is now impossible for float equipped aircraft because of this hyacinth hazard.

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*—Presented by O. W. Jordan.

**—Aviation Supervisor, State Improvement Commission, Tallahassee, Fla.

The entire Kissimmee River Valley would become a natural airway from Central to South Florida for amphibious aircraft if the hyacinth hazard was eliminated. Hundreds of lakes and other fresh water areas, would be potential landing areas if the hyacinths could be removed.

I estimate that with proper hyacinth control and eradication in Florida, we would open up at least 3,000 safe landing areas for seaplanes and amphibians. We have the natural water landing area. All we need to do is to clear them and flying safety will be increased many times.

The benefits of this program would be to the United States at large and not only to Floridians. Annually thousands of personal airplanes fly to this state from all over the country. It therefore becomes a national problem and should be considered as such.

Seaplane and amphibious flying is not highly developed in this state or other states at this time, largely due to lack of suitable facilities. Part of this is the lack of suitable landing areas. If a seaplane ramp is built in a lake in which there are floating hyacinths it is highly probable that when the pilot lands his seaplane in the lake that he may not be able to reach the float as the wind may be from such a direction as to have piled the hyacinths around the dock. A night landing in such a lake would also be extremely dangerous if floating hyacinths were encountered in the landing run of the aircraft. Consequently there is little or no night water flying being done due partially to this hazard. If we are to make the airplane really useful it must be capable of safe night operation as well as day operation.

Civil Aeronautics records of aircraft ownership show that as of June 1, 1948 there were 2964 airplanes owned by residents of Florida. Of this number approximately 10% are amphibious or equipped with floats. Florida aircraft dealers expect that at least 1,000 amphibious or float equipped airplanes will be locally owned in this state within the next 5 years. I have personally interviewed these dealers and a great many airplane owners who are looking forward to flying amphibious airplanes in our state. They want the waterways made safe for landing these aircraft.

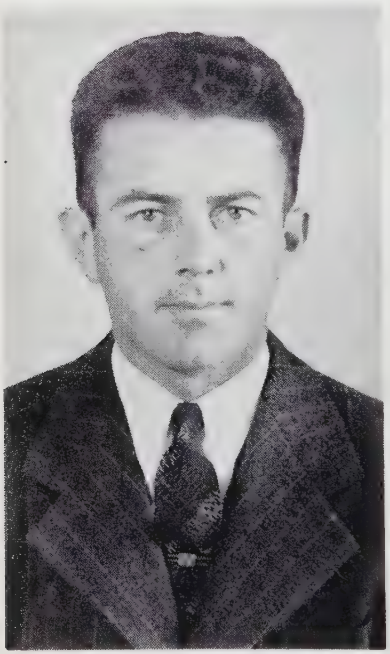
Another immediate example is at hand where hyacinths are definitely interfering with the use of aircraft. I refer to the use of a seaplane by the U. S. Geological Survey, Ground Water Division in the Kissimmee River Valley for reading the water level gages in that river. These gages are out from shore and can best be reached by use of the seaplane. However, many times the gages are so surrounded by hyacinths that the seaplane cannot get near enough to the gage to read it, even though it is able to land on open water nearby.

There are at present 35 seaplane bases in operation in the

State of Florida. Only nine of these are located on fresh water. Fresh water operation of a seaplane or amphibian is much more desirable from a maintenance standpoint. Salt water is extremely hard on aircraft parts and finishes. Why are so few of our seaplane facilities on fresh water then? One of the answers is water hyacinths. An operator can never be sure his base will be usable if hyacinths are floating in the lake or river. A wind shift can occur and make what might normally be a safe landing area a death trap. We fence all airports to keep cattle and livestock off of them to insure a safe landing area for land planes. What are we going to do for the pilots of seaplanes and amphibians?

THE WATER WEED PROBLEM FROM THE STANDPOINT OF WILDLIFE AND FISHERIES*

JOHN J. LYNCH**



JOHN J. LYNCH

We all realize that the water hyacinth and alligator weed are problems from the standpoint of the wildlife and fisheries of the Gulf Coast, but we may not be fully aware of the enormity of these problems. We know that water weeds interfere with utilization of wildlife and fisheries, but many of us overlook the fact that a considerable segment of our population depends upon these resources for recreation, food, and means of gainful employment. We now know something about the direct effects of water weeds on fresh-water fisheries, but we are just beginning to appreciate their more serious indirect effects. We are slow to recognize the potential impact of water weeds upon the total ecology of these resources.

These weeds have been a bane to sport fishermen and hunters, and the end of their troubles is not yet in sight. Thousands of acres of good fishing and hunting waters are now covered by water weeds. Additional tens of thousands of acres, although not as yet infested, can no longer be reached due to weed-blockage of canals and streams. These waterways are the highways of the wet-lands. A single acre of hyacinths or alligator weed, strategically placed, can exclude fishermen and hunters from vast tracts of marsh and swamp. This same acre of weeds may be dispersed at one time of day, so that the sportsmen can get thru to the waters beyond the block, but a shift in the wind can jam the floating weeds, and confront him with an impenetrable barrier when he returns. At best, his day of restful relaxation will end in a back-breaking struggle to get home. At worst, he may have to spend the night with the mosquitoes.

We can get some idea of the recreational importance of fish

*—Presented by T. C. Erwin.

**—Biologist, Fish and Wild Life Service, U. S. Dept. of the Interior, Abbeville, La.

and wildlife from sales of hunting and fishing licenses. In the 1946-47 season, sportsmen of the five States bordering the Gulf of Mexico purchased 227,743 Federal Duck Stamps. A large proportion of these waterfowl hunters hunt in marshes and lakes that are susceptible to weed encroachment. Florida angling license sales show that at least 75,000 resident anglers fish in fresh waters of this State each year. The famous Florida large-mouth bass contributes to the tourist business of this region, as indicated by annual sales of nearly 20,000 non-resident angling licenses. Louisiana licenses about 25,000 resident and 7,000 non-resident anglers each year. Few of the Southern States require licenses for "cane-pole fishermen," so we have no record of the number of people that fish stream-banks, canals, and roadside ditches. We would venture to guess, however, that a quarter-million men, women and children fish with cane poles, both for the sake of a family outing, and for the more serious purpose of supplementing the family larder.

Our fresh-water fisheries, in addition to their value for recreation, are important commercially. Aquatic weeds are a grave problem to commercial interests. The thousands of fishing and hunting camps in the Gulf States represent a multi-million dollar investment in camps, boats, and other accommodations for the tourist-sportsman. Weeds, particularly the water hyacinth, discourage fishing and hunting, and may completely tie-up boating for weeks at a time. Many camp operators fail to realize a profitable return on their investments due to periodic shut-downs during the tourist fishing season, and some have been forced out of business by the water hyacinth.

The commercial fresh-water fisheries of the Gulf States are big business. In Louisiana, some 5,000 commercial fishermen catch 20 million pounds of fresh-water fish, turtles, crabs and crawfish each year. Florida licenses 1,040 retail and 340 wholesale outlets for fresh-water fisheries products. The combined investment of these commercial interests in boats, gear and shore-installations runs into millions of dollars. Floating mats of weeds are a grave problem to this industry. They block the waterways that lead to fishing grounds, and tear up set-lines, nets, traps and other fishing gear. Even the salt-water commercial fisheries are affected by weeds since the shrimp and oyster-boats of Louisiana are harbored in tidal bayous that are subject to periodic weed-blocks.

Mats of water hyacinth and alligator weed are known to kill fresh-water fish. They blanket the surface of ponds and streams and reduce the oxygen content of these waters to a point below the safe limits for game and pan-fish. This destruction of fish is serious in itself, but it has an even greater significance to fish populations. Our Southern warm-water fish have tremendous reproductive capacity, and would recover rapidly from periodic disasters, provided that the total fish population, including game-fish and predacious species were killed off in comparable propor-

Figure 1.—Wind-driven Hyacinth mats interfere with boating and cause many hunting and fishing camps to suspend operations. (Lake Trafford, Fla.)

Figure 2.—Drifting Hyacinth in Bayou Grand Caillou, Louisiana. Weed jams frequently block this busy waterway, tying up shrimp and oyster boats.

tion. Unfortunately, fish-kills that are associated with weed infestation are highly selective. Game species such as the bass and the better pan-fish are the first to feel the effects of weed-coverage, since they have a higher oxygen demand than coarse fish. The gar, our most serious predatory fish, is immediately benefited, rather than hurt, by floating weeds. Being able to breathe air, the gar frequents openings in the encroaching weed-mats, and game fish that are forced to come to these openings for better-oxygenated water fall easy prey to this voracious predator. This selective kill, coupled with destruction of game-fish spawning grounds by wind-driven weed-mats, upsets lake balance. Many of our fishing waters now have unbalanced populations due to weed encroachment. This is most noticeable in some Florida Lakes such as Lake Trafford, that formerly were excellent bass waters. These lakes now have a super-abundance of pan-fish or predacious fish, but bass are limited to a few extra-large individuals that are virtually impossible to catch. The vigorous younger generations of bass that make for healthy, balanced fishing waters are absent in these lakes, due to destruction of spawn and young by pan-fish and predators.

These many indictments against the water hyacinth and alligator weed, in themselves, would justify most strenuous efforts in weed control. But there is a still graver aspect to the problem. The spread of hyacinths and alligator weed represents an insidious invasion of wildlife and fishery habitats. A gradual alteration of many of these habitats already is apparent, and further unfavorable ecological changes are to be expected.

Our Gulf Coast marshes are most attractive to wildlife in sub-

Figure 3.—Alligator weed in Cameron Parish, Louisiana. This weed not only has closed the canal to navigation, but also is invading adjacent marshlands with every high tide, destroying valuable waterfowl and muskrat habitats.

Figure 4.—Floating mats of alligator weed are impassible in conventional powerboats.

Figure 5.—This abandoned reclamation district in Louisiana (aerial view) was highly productive of fish and waterfowl prior to invasion of water hyacinth. The rapid growth of hyacinth (dark areas on photograph) is now taking over the last open water areas, and floating marsh (the lighter patches on the photograph) that is developing on older hyacinth mats will ruin this lake for all time.

climactic stages. Prolonged freedom from disturbance permits development of edaphic climax. Climax marshes are relatively worthless for wildlife. Nature discourages climax by catastrophic disturbances such as drouth, fire, floods, hurricanes, and animal overpopulations. In our studies of marsh management we have found it possible to duplicate, and in some cases improve upon, the beneficial results of these drastic natural treatments by judicious use of fire, grazing, water manipulation, salt-water intrusion, and mechanical as well as "biological" cultivation. Our fundamental aim in marsh management is the reversal of plant successions to the submerged aquatic and emergent stages, since these are the best wildlife habitats. Unfortunately the introduced water hyacinth has proved to be far more successful in the fresh-water hydrosera than are any of our native submerged or floating-leaved aquatics. Alligator weed has found a most favorable niche in the emergent zones of our fresh and slightly-brackish marshes. Once established in these respective zones, these pest plants totally eliminate the native species that furnished food for waterfowl and fur animals. In effect the hyacinth and alligator weed usurp the place of the more desirable plants in the secondary succession. Hyacinths may completely by-pass the aquatic and emergent stages in our fresh-marsh succession, and precipitate an undesirable climax, since their durable floating mat becomes a substrate that permits immediate invasion of climax species.

Our knowledge of marsh management for wildlife is increasing each year. But any of the management measures now available, and any that are likely to be devised in the future, will be concerned with maintaining plant associations in their lower successional stages. Water hyacinths and alligator weed have demonstrated an amazing capacity for usurping and dominating these stages. Thus the hyacinth may utterly defeat our management efforts in the fresh marshes, and alligator weed capitalizes on our management of the brackish marshes for waterfowl and muskrats by taking them over. To put it bluntly, cultivation of these marshes for wildlife is fast becoming tantamount to cultivating them for the growth of water hyacinths and alligator weed.

We are beginning to revise some of our earlier concepts of the ecology of fishery habitats. Viosca* first called our attention to the importance of overflow lands in fishery food-chains of the Mississippi Flood Plain. He pointed out that fish of the swamp lakes and streams derived much of their food from adjacent flood-bottoms, and showed that any diminution in fertility of the overflow lands would be detrimental to these fisheries. We find that a similar situation exists in the fisheries of our coastal marshes. A small marsh pond, only a few acres in extent, may

*—Viosca, Percy J. "Flood Control in the Mississippi Valley in its Relation to Louisiana Fisheries." Tech. Paper No. 4, La. Dept. Conservation, 1928.

Figure 6.—Alligator weed moving down a tidal bayou into the brackish marshes. High salinities discourage this weed temporarily, but it recovers rapidly as soon as tide-waters are diluted by rains.

Figure 7.—When water hyacinth invades swamps and backwaters, it may play havoc with vital fishery food-chains. (Bayou Lacassine, Louisiana).

yield an amazing tonnage of fresh-water fish. Such yield, if expressed in terms of production per acre of open water, would stagger the imagination. The situation comes into clear focus, however, when we realize that possibly a thousand acres of the surrounding marshlands have contributed materially to productivity of the pond. In speaking of fishery habitats of the coastal marshes, we, therefore, must take into account not only open waters, but all contiguous backwaters and overflow lands, including those that are flooded only intermittently.

The brackish marshes are important in maintaining our coastal salt-water fisheries. The extent of their contribution remains to be determined, but it is obvious that these marshes must be considered supplementary habitats in the total ecology of the shrimp, oyster, and crab fisheries of our coastal waters.

Water hyacinths already are well-established in the overflow habitats of our fresh-water fisheries, and alligator weed is rapidly taking over the upper tidal habitats of our shore-fisheries in Louisiana. We are not yet in a position to predict the final outcome of this alteration of habitats, but the information at hand is not encouraging. We know that marsh and swamp backwaters are de-oxygenated by weed coverage, and their production of plankton drastically lowered. We have observed that decomposing mats of alligator weed, especially in brackish water, produce quantities of hydrogen sulfide, a gas that is highly toxic to fish and other aquatic organisms. Further investigation of these possibilities is imperative. While awaiting more definite information, we are moved to express grave concern over the invasion of backwaters and overflow lands by hyacinths and alligator weed. We consider these weeds capable of interrupting the vital fishery food chains that originate in these habitats. Pockets of toxic materials generated by decomposing weeds can have disastrous effects when swept into nearby permanent waters by heavy rains.

Our wildlife and fisheries are renewable resources. Many of us interpret the term "renewable" as meaning only that our sporting and commercial harvest of these resources will be compensated for by Nature's bounty. To the ecologist, the term signifies that these resources not only *can* be renewed, but *must* be renewed if they are to be perpetuated. Such renewal is possible only to the extent that the productivity of wildlife and fishery habitats is renewed and maintained. Nature accomplished such renewal in a somewhat hap-hazard manner, and the wildlife and fishery manager seeks to create and maintain these habitats by more orderly means. But water hyacinths and alligator weed have an unhappy faculty for taking over the most valuable niches in our wildlife and fishery environments. In so doing, these weeds can utterly defeat the combined efforts of Nature and man to maintain these environments. Only when we fully awaken to these facts will we begin to appreciate the enormity of the danger that confronts the wildlife and fishery resources of this region.

THE CONTROL OF WATER HYACINTHS BY MECHANICAL MEANS

A. H. Brown*

A. H. BROWN

The plants and the problem they create have been described to you by several able gentlemen. This paper discusses the solution or control of water hyacinths by mechanical means. Mr. Wunderlich** has discussed the "Type, adaptability and limitations of mechanical plant under Louisiana conditions," and I shall follow up on the same subject under Florida conditions.

Before proceeding on that subject I want to speak briefly on the existing Federal project which authorizes the operations of the Corps of Engineers for removal of water hyacinths in the State of Florida.

It appears to be the general opinion of those interested in the control of the pest that the Corps of Engineers has the authority and the responsibility to remove the plants wherever they are found and for any purpose. The facts are quite different. The various River and Harbor Acts which authorize the operations provides only for "Removal or destruction of the water hyacinth in the navigable waters of the State of Florida so far as they become an obstruction to commerce."

That of course confines the operations to navigation channels. Funds are made available accordingly and all mechanical plant that has been used to date was designed to operate in the navigation channels where the water depths are such as to provide flotation. It is needless to tell you that the operational area to which we are limited is very small compared to the extensive lake and other non-navigation areas in the state which are infested with the plant.

The River and Harbor Act of 1905, still in effect, also pro-

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*—Chief, Operations Division, Corps of Engineers, Jacksonville, Florida, District.

**—Unfortunately Mr. Wunderlich of the New Orleans District Office could not be present and present his paper. Ed.

hibits the use of any chemical spray that may be harmful to cattle or fish.

Now as to the mechnical means we have used. First, the derrick and grapple. When the plants are permitted to grow to maturity during spring and early summer the late summer and fall rains cause flood conditions that drift them into the main channels. There, with the current and wind, the plants are jammed against bridges or in restricted reaches and are rolled into dams several feet in depth. When this condition develops the derrick

Figure 1.—A large derrick boat operating in the north fork of the St. Lucie River, 1939.

and grapple is the only practicable means of removal. The use of the equipment is limited to just such situations. The photographs of Figure 1 and 2 show this equipment in operation.

Next we take up the conveyor. Several types were constructed and used over the period from 1909 to 1941. Conveyors of all types proved to be impractical for general use under Florida conditions. None are in use at the present time. I can best describe them by the photographs of Figures 3 to 6, inclusive.

The 1940 model was quite a machine. Note the wide pick-up conveyor which moved very slowly and was equipped with forks operated from a crank through a link motion to reach out and pull the plants in contact with the conveyor lugs. Aft of the pick-up conveyor is the discharge conveyor set cross deck and mounted in a trunnion at the center to permit either end to be elevated for discharge to either side. We accomplished something on the cross conveyor that the manufacturers of roller chain said could not be done. We operated this conveyor at about 1,000 feet per minute, the idea being to shoot the plants well up on shore. It worked well and the chain never gave any trouble. The problem

Figure 2.—A dragline operating from a barge to clear one of the navigation channels in Lake Okeechobee, 1927.

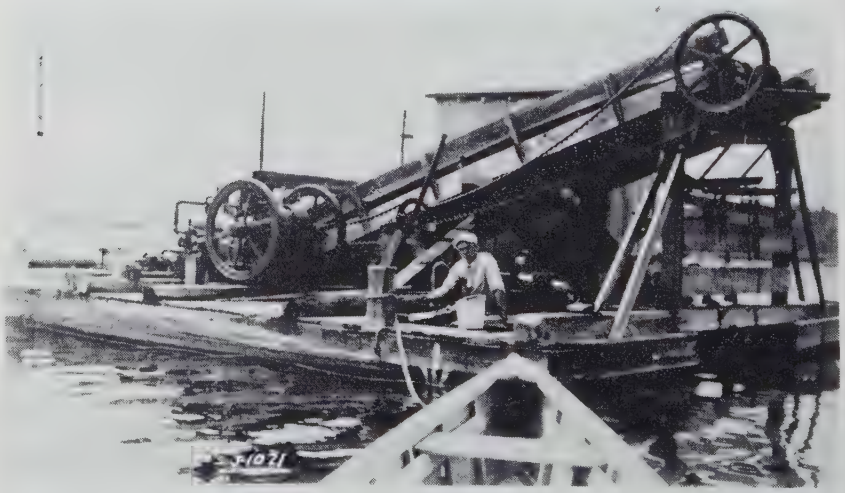


Figure 3.—A 1909 model conveyor used on the St. Johns River.

was to get the plants to and on the pick-up conveyor. Cost of operation was high and output low. The idea was good but these floating hyacinth plants have a way of disappointing you.

I therefore repeat the opinion that elevators are out of the picture as a means of efficient and economical handling of these weeds.

Thirdly, and after we had proved that derricks with a grapple and various types of conveyors were not the answer we found the best mechanical means yet used. Mr. Charles R. Short of Clermont, Fla., a retired Research Engineer, developed the idea. He equipped a small boat with a bank of gin saws which were mounted on a mandrel and set just forward of the boats bow. The saws were actuated by roller chain and sprockets from the propelling engine. After observing the efficient operation of the boat it was purchased by the Corps of Engineers for further tests and study.

From it we developed the present destroyer boats now in use. The destroyer is a boat 17 feet in length with a beam of 6 feet. Three groups of saws are mounted on the boat. The forward group consists of two banks of saws each 3 feet in width actuated independently. The after groups, 1 port and 1 starboard, each 3 feet wide, are mounted on outriggers so as to make a cut 12 feet wide. The saw disks are 12″ in diameter with "V" type teeth and turn at about 1,000 rpm. An industrial type power unit of 50 h.p. provides the power which is transmitted to the saw banks through a standard light truck rear axle assembly and thence by roller chains and sprockets. No propelling unit is required. Friction on the rotating saws propel the boat and at the same

Figure 4.—A 1920 model conveyor used on the Withlacoochee River in 1922.

Figure 5.—A machine designed and constructed by the New Orleans, La. District which we obtained in 1939. It is shown clearing the Hillsboro Channel in the Everglades.

Figure 6.—A 1940 model conveyor (No. 3) working in the St. Johns River near Sanford.

time create a current that draws the floating plants into the saw banks.

The boats are light and are operated usually by two men. The area that can be covered in one 8-hour day varies with the density of the plants; in densely infested areas when plants are up to 45 inches in height 2 to 4 acres per 8 hours and up to 8 to 16 acres in the same time in less dense areas of small plants.

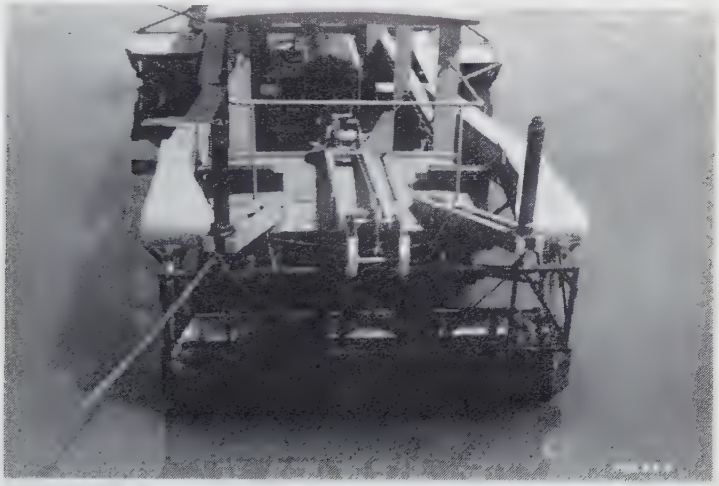


Figure 7.—The hyacinth destroyer—looking at the bow. The blades, rotating at 1000 RPM, propel the boat as well as cut the hyacinths.

Figure 8.—The job. Arbuckle Creek, completely closed, before cutting.

Through the season of operations a boat operating in various locations will cover an average of 8 acres per day at an average field cost of $7.00 per acre. These boats will not operate efficiently in water less than 1.5 ft. in depth.

The saw boats effectively and quickly open channels to navigation and are quickly and easily transported from one location to another. Experience has shown that less than 5% of plants cut by the destroyers will survive. The photographs of Figures

Figure 9.—One cut through the jam with the hyacinth destroyer.

Figure 10.—Further progress has been made with a considerable channel apparent through Arbuckle Creek.

7 to 12, inclusive, will give a better idea of the destroyer and its operation than can be put in words.

These destroyers are adapted to operate in navigable waters and are effective in clearing channels for navigation. You will note on the photographs the rim of plants left on each bank. The destroyers cannot reach them, nor can these destroyers reach many other great areas where the plants propagate and grow.

In closing let me say that we shall never control these pests by mechanical means alone. Nor shall we ever reduce them by

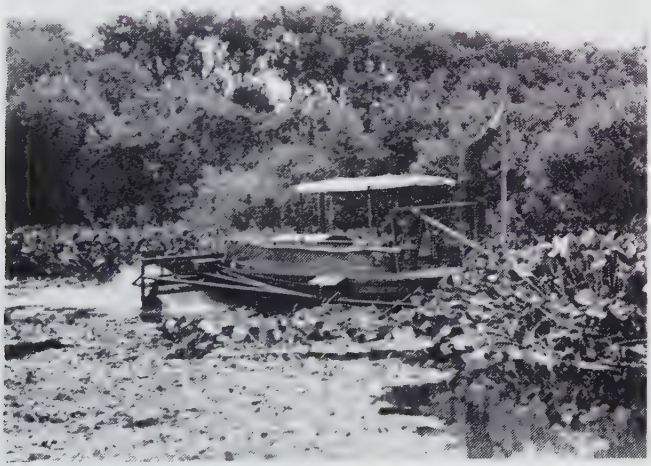


Figure 11.—A close-up of the destroyer in operation

Figure 12.—Channel open with most of debris gone and only fringe growth of hyacinths remaining.

merely keeping channels cut through them. If effective control is to be obtained it will be obtained only by the fullest cooperation of all interests, private, local governmental agencies, state agencies and Federal agencies working on a coordinated plan to destroy the pests at the source, not only for navigation, but for all other purposes.

Any program must utilize both mechanical and chemical means. If the problem is properly attacked and the pests are controlled at their source the only mechanical means then required would be the necessary plant and equipment for practicable and efficient application of the chemical sprays.

MANUFACTURE AND FORMULATION OF 2, 4-D AND 2, 4, 5-T

HOYT A. NATION*

HOYT A. NATION

The purpose of this paper is to explain as briefly as possible the meaning of the term 2, 4-D and to give some understanding of the various formulations of this compound. In order to fully understand the meaning of the term 2, 4-D it is necessary to understand a few relatively simple formulas. No attempt will be made to show exactly how 2, 4-D is made but the different steps in its manufacture will be briefly discussed and a few formulas drawn to clarify our discussion. An understanding of the term 2, 4-D will help to explain other terms like 2, 4, 5-T of which you have heard or will be hearing soon.

2, 4-D is an abbreviation of 2, 4-Dichlorophenoxyacetic acid. Four materials used in the manufacture of this material account for its name.

The first of these materials is benzene which is responsible for the two numbers. Benzene is a product obtained when coal is changed to coke. Organic chemists generally give this material the structural molecular formula shown in Figure 1 and represent this formula by a hexagon as shown in Figure 2. It will be noted from the first figure that a molecule of benzene contains six carbon atoms connected to form a ring by a series of alternate double and single bonds. Each carbon atom has attached to it one hydrogen atom. In chemical reactions it is very difficult to break the bonds between the carbon atoms but very easy to replace any or all of the hydrogen atoms by simply controlling the chemical reaction. It is this feature about benzene that makes it useful not only in the manufacture of 2, 4-D but in many other organic compounds such as DDT and BHC. The chemist uses the hexagon to represent the benzene molecule or benzene ring as it is commonly called because it is much simpler

*—Technical Service and Development, The Dow Chemical Company, Midland, Michigan and Auburn, Alabama.

to construct than the actual formula. When the hexagon is used it is understood that each angle represents one carbon and one hydrogen atom. Because it is possible to replace one or any combination of hydrogen atoms on the benzene ring by certain reactions and because when two hydrogens are replaced on the ring the position of the hydrogen replaced determines to some extent the characteristics of the compound produced (as will be seen later) it is necessary to identify what position in the ring the reacting atoms occupy. For this purpose the angles of the hexagon, or the carbon and hydrogen atoms, are numbered from one to six starting at any point on the hexagon and numbering in a clockwise direction. It is this numbering of the position of the reacting atoms that accounts for the numbers 2 and 4 as will be explained later.

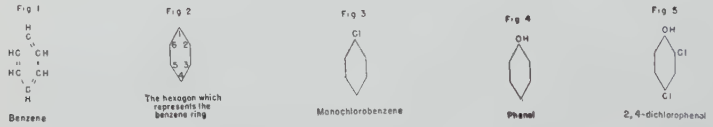
The second part of the name is di which means two.

The third part is chloro which indicates the product contains chlorine. When one has an understanding of organic chemistry he can put the above information together and he will know that the material contains two chlorine atoms and that they are on the number 2 and 4 carbons, or angles. Had they been on the 2 and 5 or 2 and 6 position we would have had a product similar to 2, 4-D but differing somewhat in its reaction from that of 2, 4-D.

The fourth part of the name, phenoxy, indicates that phenol or carbolic acid is used in the manufacture and the fifth part, acetic, indicates that acetic acid is also one of the compounds used. Incidentally, vinegar contains acetic acid.

Now that we have explained what the various parts of the name mean, let us take a look at some more formulas to get a better understanding of what actually happens. In the manufacture of 2, 4-D one atom of chlorine is first added to the benzene ring and it is placed on the number one position. This material is a liquid and is called monochlorobenzene. See Figure 3.

Then this material is reacted with sodium hydroxide (NaOH). In this reaction the chlorine is replaced by the OH group and combines with the sodium to form NaCl or common salt. The benzene ring has now become phenol. See Figure 4.



By heating the phenol and bubbling in chlorine, a chlorine atom is placed on each of the number 2 and 4 carbons. This material is known as 2, 4-dichlorophenol and is shown in Figure 5. These reactions account for the "2, 4-dichlorophenoxy" of our compound name.

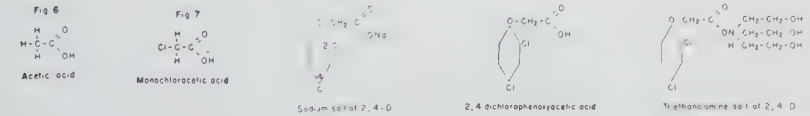
We now take acetic acid as shown in Figure 6 and add one chlorine to it as shown in Figure 7. This material is known as chloroacetic acid. By combining chloroacetic acid and 2, 4-dichlorophenol with NaOH, a solution of the sodium salt of 2, 4-D is produced. See Figure 8. The percent 2, 4-D in this solution is low. The sodium salt sold on the market is not the solution produced in this step of manufacture, but is a powder produced by combining the free 2, 4-D acid with caustic soda or sodium carbonate. Pure 2, 4-D is made by treating the sodium salt solution mentioned above with HCl and has the structural formula shown in Figure 9. This is a white crystalline material that is practically insoluble in oil or water. By replacing the H of the OH group of the acetic part of the formula with various materials the different formulations of 2, 4-D are made and these formulations are either soluble in water or in oil as discussed later.

2, 4-D formulations can be separated into two major groups. These groups are salts and esters. A salt is produced by reacting an acid with a base and an ester by reacting an acid with an alcohol.

The salts of 2, 4-D are soluble in water but not in oil whereas the esters are soluble in oil but not in water.

The salts of 2, 4-D can again be divided into two groups; the metallic salts and the amine salts.

The sodium salt of 2, 4-D is the most common of the metallic group and is prepared by reacting the free acid of 2, 4-D with sodium hydroxide or sodium carbonate. This material is a powder soluble in water and containing a high percentage of 2, 4-D. A study of Figure 8 will show that the sodium atom replaced the hydrogen atom on the OH group of the acetic acid formula.



The following discussion is a purely figurative and simplified way to illustrate how 2, 4-D amine salts are formed. The alkanolamine salts can be represented by the triethanolamine salt as shown in Figure 10. These salts are liquids soluble in water and are made by combining *ammonia, alcohol and* 2, 4-*D acid.* In the case of the triethanolamine, three molecules of ethyl alcohol (the kind used for drinking) might be used. This alcohol is known to the chemist as ethanol. Since three molecules are used, this accounts for the triethanol and since ammonia is also used this explains the term triethanolamine salt. The whole group of salts that can be produced by combining the various alcohols with ammonia and 2, 4-D are known as the alkanolamine group

and any salt of that group may be properly called an alkanolamine salt.

Since esters are made by reacting an alcohol and an acid, it is possible to make quite a number of different esters. At least five esters have been or are being produced commercially; they are methyl, ethyl, insopropyl, butyl and amyl. There seems to be no practical difference in the potency or activity of the various metallic salts, the various alkanolamine salts or the various esters, but there are differences in activity among the three groups as a whole. The metallic salts are the least plant toxic, the esters, the most, and the alkanolamine salts somewhere intermediate between the two. The salts are generally considered more safe to use on crops for selective weed control. The esters are often more effective against woody plants and certain herbaceous weeds.

Until recently the alkanolamine salt formulations have been used largely in high volume spraying and so were most of the other formulations. With the advent of low volume spraying, amine and ester formulations have been developed that meet the demands.

I think it fortunate for the Everglades that pioneer work in low volume spraying has been done here. Dr. R. V. Allison, Mr. Charles Seale and Mr. Jack Evans did small plot work and Mr. Lamar Johnson, cooperating with the aviators in this section, has developed methods for large scale hyacinth control. The idea has been carried to field sprayers and low volume application is being used extensively in the spraying of crops.

I believe attention should be called to the fact that the esters on the market at present are volatile to some extent while the salts have little if any volatility. This means that when an ester is used near a susceptible crop like cotton, the crop may show 2, 4-D effect even though it was thoroughly protected from spray drift. This effect is caused from the fumes coming into contact with the crop and the effect can be produced several days after spraying should the wind blow off the sprayed area onto the susceptible crop. For this reason the salts are somewhat safer and should be used, if effective on weeds to be controlled, when susceptible plants are growing in the vicinity of the area to be treated.

In making the various formulations of 2, 4-D the manufacturers have seen fit to vary the percentages of 2, 4-D in their products. It should be remembered that the 2, 4-D (or 2, 4-D acid equivalent) is the significant point of comparison among formulations or products and that one should not expect the same results from a quart of a 10 percent solution as from a quart of a 40 percent product. Therefore, the percent 2, 4-D in a product must be known to allow intelligent comparison of prices and the formulation of correct recommendations for the

use of the material. Each manufacturer shows, or should show, on the label of each of his containers the percent of 2, 4-D (or 2, 4-D acid equivalent) contained in the formulation. Therefore read the label when comparing prices of materials or making use recommendations. Sometimes labels may not state whether the 2, 4-D formulation contains a salt or an ester but this can be determined by pouring a few drops of the material in water. If the water takes on a milky appearance the material is an ester; if no milky color is observed the material is a salt.

Now for a very brief discussion of 2, 4, 5-T. This is the abbreviation for 2, 4, 5-trichlorophenoxyacetic acid. This is the same type material as 2, 4-D but, as the name suggests, it has an extra chlorine atom in the number 5 position on the benzene ring. 2, 4, 5-T is more effective than 2, 4-D on our southern blackberries, osage orange and certain other hard-to-kill plants. An isopropyl ester formulation of 2, 4, 5-T is now being produced in limited quantities and will be available for 1949. For general brush control it has been found that a mixture of an ester of 2, 4-D and an ester of 2, 4, 5-T is very effective.

A REVIEW OF EFFECTIVE GROUND- AND WATER-BORNE EQUIPMENT FOR THE CHEMICAL CONTROL OF WATER PLANTS

JOHN W. RANDOLPH*

Many of the herbicidal materials used in the control of water plants have no unusual physical characteristics. That is, most of these chemical compounds can be handled by some form of conventional equipment normally used for overland distribution of dusts or liquids. In the water-borne approach the transportation facilities themselves and the attachments regulating final dispersal of the herbicide are about the only appreciable departures from dust spray or spray units used in land operations.

Undesirable water weeds are frequently so located within natural or artificial waterways that they are virtually isolated insofar as their accessibility through the use of common forms of transportation is concerned. Effective and economical use of any herbicide material depends very largely on the exact dosage applied under a given condition. The desired pattern of dispersal and the rate of delivery per acre of a chemical mixture involve a series of problems that can be worked out best through a preliminary selection of equipment and the adjustment of the required attachments. Unit rate of application of herbicides over water generally is highly variable due to the difficulty of maintaining a uniform rate of travel under water-borne conditions of transportation.

Certain areas of water weeds may be in favorable locations and are accessible to land spray or dust rigs with minor modifications. When such conditions exist, then the lowest cost of weed control can be expected. Under inaccessible conditions, however, the transportation costs of the chemical applicator and the needed crew may represent such a high ratio of total costs that it is often advisable to use a herbicide in excess in order to obtain a maximum effect from the treatment with a minimum movement of the equipment. Water weeds in close proximity to economic plants, whether crop or ornamental, necessitate the use of accurately controlled methods in the application of most herbicides. A good rule to follow where there is any question of danger to the vegetation of adjacent areas is "don't spray."

Water weeds, insofar as the problems of equipment for chemical application are concerned, can be divided into two general classes: (1) exposed or surface weeds and (2) under-water weeds. The herbicides used also can be divided into two general classes: (1) materials that are effective when deposited from the air and (2) materials that must be added to the water with varying degrees of mechanical mixing.

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*—Agricultural Engineer, Everglades Experiment Station, Belle Glade.

Herbicide Equipment for Exposed Water Weeds

Hyacinths represent exposed water weeds that can be effectively controlled by surface applications of 2, 4-D or killed back with a contact material. Large open areas of water covered with a dense growth of hyacinths offer a favorable location for the use of the airplane equipped with a low gallonage 2, 4-D spray applicator. Mr. A. E. Holland, a speaker on this program, will explain the advantages of the airplane for use in large, mass killing of hyacinths and also outline for you what water weed locations are inaccessible for the practical use of the airplane and the kinds of herbicides that cannot be properly applied from the airplane.

The Everglades Drainage District used the airplane quite extensively to apply 2, 4-D for killing the long continuous masses of well-exposed hyacinths in the arterial canals of South Florida. The first operation, commonly called the "mass-kill," was very effective except on areas protected by certain forms of barriers which prevented exact applications of the chemical in this manner. Other agencies likewise have obtained excellent results in mass-killing through the use of the airplane 2, 4-D applicator on large, favorably located areas of hyacinths and on follow-up sprays after the hyacinths that escaped the first spray have reassembled.

Old hyacinth growths and areas of high hyacinth compaction, caused by stream flow or wave action, represent conditions virtually impassible for conventional forms of boats. The U.S. Army Engineers and certain South Florida drainage districts have equipped special boats with cutter heads that open up a passage for the boat fitted with a herbicide applicator. The most common form of a cutter head for a "saw boat" is a series of large diameter saws mounted on a mandrel across the bow of the boat. The saw action is to slit the growth and to force it under the boat, the traction of the saws on the hyacinth growth being a means of obtaining forward travel as described earlier in the program by Mr. A. H. Brown.

Many experimental units have been designed to use a single slitting saw and side traction chains to pull a boat through a hyacinth growth. Few references are available to indicate that such designs have received extensive practical use.

Water weeds and other undesirable vegetation produce rank growths on shallow water areas, impassable for most boats. The game hunters of the Florida Everglades have developed a so-called "frog boat," which, in jest, has been considered capable of navigating on a good dew. In actual operation the frog boat can be floated on a few inches of water and can travel over a light growth of sawgrass and other water weeds. This boat is generally powered by a small airplane motor with a conventional

air propeller, and is steered by an air rudder. With no means of reversing the direction of travel, the frog boat will have certain limitations in the application of herbicides in areas with many obstructions.

The Armed Forces developed many forms of landing craft and water vehicles during the past war. Frequently, the dense growth of water weeds and the tractionless value of the soil and sludge under the water growth prevent the use of the military forms of vehicles.

Oil prospecting organizations have developed and constructed several forms of amphibious craft that might be extremely useful in chemical weed control in marsh lands. Conventional four-wheel drive trucks and cars have been modified for use by employing oversize tires and wheels or increasing the underclearance by use of stub axles and chain drives. Figure 1 shows

Figure 1.—Marsh Buggy, developed and constructed by Humble Oil and Refining Company.

the "Marsh Buggy" used by Humble Oil & Refining Company. A similar unit, the "Mudhopper," is described in detail in The Oil Weekly, September 23, 1946. The Gulf Refining Corporation have used a "Swamp Buggy" that was equipped with extra large balloon rubber tires that floated the unit in open water.

The Everglades Drainage District has made extensive use of their water truck as shown in Figure 2. This unit furnished the transportation for a high-pressure pump unit that was used to spray 2, 4-D through a brush hand gun as shown in Figure 3. In brief, this water truck consisted of an auto chassis equipped with four large steel cable spools that had been made air-tight by surfacing with plywood and then fitted with 2x4 inch timbers to

Figure 2.—Water Truck with spraying equipment designed by Everglades Drainage District, and constructed by Everglades Experiment Station.

Figure 3.—Spray Brush Gun, a high-pressure nozzle with hand control for variable distance delivery and shut off of liquid.

give traction. The wheels, six and one-half feet in diameter, require a relatively slow speed of rotation; hence, it was advantageous to use a six horse power gasoline engine with a 15 to 1 added speed reduction to that contained in the regular transmission and rear axle. While this water truck has certain limitations in maneuverability and it is not free from serious breakdowns, the unit still represents one practical method of transportation for the application of chemicals under very difficult conditions.

Spray Equipment

The cutter head boat, the water truck, saw boat and the other means of transportation into jammed hyacinth growths make it desirable to spray or dust a very large area with the least amount of travel. Air currents can be used to aid the drift of dust applications applied from high velocity dusters if surrounding conditions will permit. Mist distributors, such as the Buffalo Turbin, have been used to cover a wide area with a herbicide by means of a drift. The Everglades Drainage District and other drainage units in Florida have used the basic elements of a high-pressure orchard spray quite extensively for the application of 2, 4-D. The final dispersion of spray has been through a conventional tree or weed hand gun. These spray guns, manually controlled, can be directed as desired to cause the discharge to go some distance before the final breakup or to produce a fine mist distribution in close proximity to the operator. With the selection of available orifices and differences in pressure applied on the spray solution, the final particle size and range of distribution of spray can be varied widely. It should be emphasized, however, that these types of 2, 4-D applicators should not be used near sensitive vegetation.

Hyacinth growths in narrow fringes, scattered groups, and in regular patterns in open water are logical locations for use of low gallonage, concentrated herbicides. The Everglades Experiment Station, in cooperation with the supervisors of local drainage districts, have worked out several forms of low cost applicators for patrol work from boats and land vehicles.

Attention is called to a low gallonage spray unit made for the Everglades Drainage District (see Figure 4). The boat is a light weight skiff made of ply wood and is powered with a standard outboard motor. The distributor consists of a small gas engine and a small gear pump with "V" belt drive. A ball-spring pressure relief valve is so connected in line as to maintain the desired liquid pressure and to by-pass the surplus pumped liquid into the storage tank, thereby keeping a well-mixed solution. A fine mesh screen or filter is used to keep the discharge line free of foreign matter that might clog the small orifices in the nozzles. Clusters of hyacinths along a canal bank were sprayed with 2, 4-D from a light weight "wand" distribu-

Figure 4.—Low gallonage spray unit mounted on boat. (Everglades Experiment Station)

tor made by Spraying Systems Company. Variable width borders of hyacinth along the canal bank were sprayed with an outrigger boom equipped with several nozzles, each with a quick-acting shut-off valve. Both forms of spraying were possible at a moderate boat speed. This system represents a low cost patrol program for eliminating the potential regrowth areas.

The small, gasoline engine gear pump unit, through increasing the liquid pressure, was used for operation of a single nozzle brush gun as explained for high-pressure spraying by increasing the liquid pressure.

Records are available on land spray rigs in the west that are equipped with very elaborate outrigger booms for low and high gallonage spraying over irrigation canals. The adaptation of hydraulic controls and use of suitable linkage can make a spray boom quite flexible in respect to location and range of effective action.

Herbicide Equipment for Underwater Weed Control

Most underwater herbicides are effective in definite concentrations, usually expressed in parts per million, and with a given dispersion maintained for a specific time period. These specifications involve the consideration of several hydraulic factors associated with the determination of the quantity of water to be treated and mechanical factors of metering the chemical materials and their dispersion.

Slow flowing streams or water areas subject to artificially controlled rates of flow, offer many advantages through the use

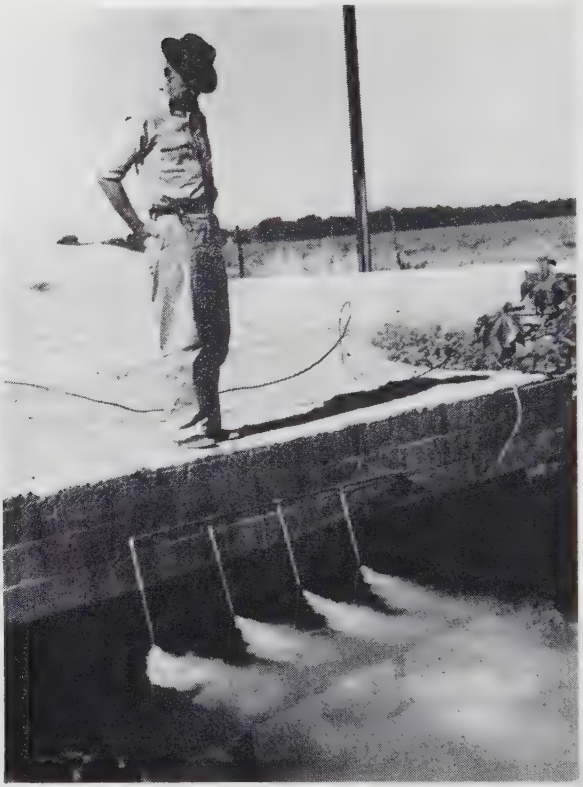


Figure 5.—Fixed station delivery of spray into stream.
(Photo courtesy Cloroben Corporation)

of a chemical applicator at a fixed station as shown in Figure 5. Some herbicides are effective in discoloring the flowing water in a way that is helpful in determining distribution. The initial up-stream point of application may consist of a simple power unit that will deliver the required amounts of materials into the water through any number of spray nozzles of predetermined type. Successive down-stream stations for herbicide application will depend upon losses of the active chemicals and dilutions resulting from water entering from side drainage areas. Adjustments in the rate of flow in artificially controlled streams and careful regulation of chemical applications can result in very effective weed killing with the use of minimum amounts of materials.

On the other hand, herbicide materials which cannot be evaluated in their distribution by water color changes (note Figure 6) require careful calculations to obtain the desired rate of application.

Figure 6.—Rate of spray delivered indicated by discoloring of water. (Photo courtesy Cloroben Corporation)

Underwater weeds are highly objectionable in drainage areas which have very low rates of flow. Under such conditions the erratic secondary channels of flow are of little value in assisting with the uniform mixing of the weed-killing chemicals. Under such conditions some form of equipment transportation must be used to work out a pattern of uniform application of the herbicide. Dense underwater weed growths usually offer considerable resistance to common methods of propelling a surface craft. The so-called weedless propellers are effective under certain conditions. Paddlewheels so constructed that weed growth cannot tangle or adhere to the wheel have been used, an example of which is shown in Figure 7. Frog boats, marsh buggies and other special water craft will be effective within rather broad limits of use on waters filled with submerged weeds.

The distribution of liquids in still water and their adequate mixing into a body of weeds which it is desired to destroy may present a number of mechanical problems. If the chemical is

Figure 7.—Boat with paddle wheels.
(Photo courtesy Cloroben Corporation)

more or less stable and has a high rate of diffusion or self-distribution through a weed mass, then a few points of application may be simple. A power spray rig can be used to supply the required chemicals through metering nozzles after mounting in a suitable transportation unit. Shallow underwater placement of a herbicide can be obtained when the nozzles are mounted on a vertical drop boom extension. When these are set at a moderate back angle clogging and pulling of the underwater weed growth largely will be prevented. The typical discharge from a chemical metering unit generally does not have sufficient velocity to create a real mixing effect in the volume of water to be treated.

High volume, high pressure pumps are capable of creating adequate turbulence adjacent to discharge into a large volume of water. The injection of the chemical mixture into the suction line of the large pump offers, on paper, a simple way of mixing chemicals into still water. In practice, however, there are many troubles due to the problems of transporting heavy power pump equipment under such conditions and, most important, the development of a suitable screen for the intake of the big pump.

Chemical applications with multiple nozzles at several depths can be obtained in a body of water by two general methods with minimum clogging in the weed growth. (1) The main boom with nozzle extension could be given a cycloid motion by mechanical devices attached to the transport unit. (2) A sled runner boom extension could place the nozzles in protected locations

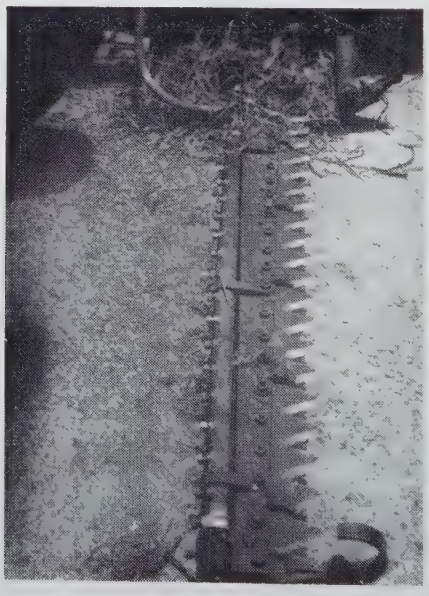


Figure 8.—Spray nozzles attached to cutter bar of mowing machine. (Everglades Experiment Station)

above the lowest level of the runner but below the water surface at predetermined depths. In some cases, a circular saw in front of the sled runner would help prevent clogging and give uniform depth of operation.

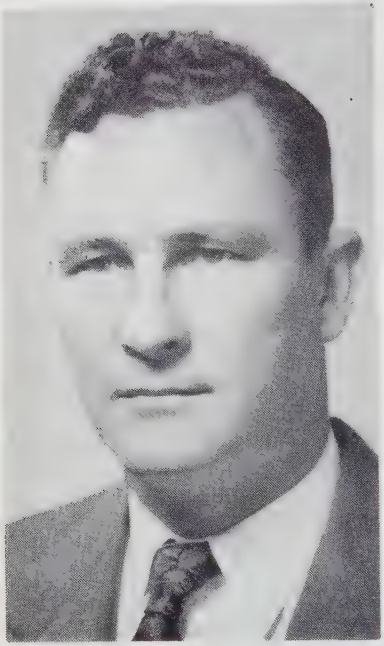
Matured growths of water weeds, like land weeds, require excessive amounts of chemicals to obtain a kill. Mechanical mowing and covering the ground root area with a concentrated application of herbicide offers a new approach to this problem. Figure 8 shows a special spray boom, constructed at Everglades Experiment Station, with many nozzles attached to the rear of a mower cutter bar equipped with stub guards. This unit gave a low and effective spray placement under very dense vegetation that was difficult to cut with long-nosed mower guards.

Off-Center Spray Nozzles

The Spraying Systems Co., Bellwood, Illinois, has recently developed a series of nozzles having a wide off-center fan-spray distribution, the spray being of relatively large particle size, suitable for 2, 4-D surface contact spraying. These nozzles are available in a dual assembly called "Boomjet Nozzles." Through selection of size of orifice, liquid pressure, location above surface, etc., the assembly can give a wide range in rates and width of swath, for example, from 6 to 60 feet. This Boomjet, in single application, eliminates the need for a boom, which is a source of many difficulties when spraying in obstructed locations. The "OC" series of nozzles are so designed that they will pass relatively large particles of foreign matter in a spray solution. In practice, this means that less care is required in screening the water used in the spray mixture. Thus it may be possible for a boat spray unit to use water directly by suitable injection into a 2, 4-D spray mixture.

EFFECTIVE AIRBORNE SPRAY EQUIPMENT FOR WATER WEED CONTROL

A. E. HOLLAND*



A. E. HOLLAND

There are any number of variations in the equipment for aerial dispersal of herbicides. However, that which has come to be regarded as the more conventional is the light plane equipped with a tank, a blast-propelled pump and a boom arrangement with nozzles or other outlet.

By light plane, we refer to the small sportsman-trainer type with horse power ranging from 65 to 90 h.p. or the slightly heavier primary trainer type with horsepower ranging from 200 to 300. Tanks installed have a carrying capacity from 35 to 85 gallons of material and may be either of two general types. The internal tank which takes the place of one of the cockpits, is a permanent installation and has the advantage of carrying no additional drag to decrease the performance and maneuverability of the plane. The external tank, generally with a capacity of 83 gallons, is a detachable streamlined fuel tank converted for this particular use.

The pump, powered by a small fan extended into the propeller blast of the plane develops operating pressures ranging from 25 to 45 pounds depending on the number of nozzles, the size of orifice within the tips or other outlets if open boom arrangement is utilized.

For the express purpose of applying herbicides, check valves affording quick, positive cutoff is highly desirable as protection against a drool resulting in loss of material in areas not intended to be treated. In many instances, these "areas" may be susceptible crops and the results are disastrous. Nozzles, with various interchangeable tips, or orifices, are one means of chang-

*—World War pilot, Bartow, Florida, Mr. Holland is highly experienced in air service work for agriculture and did a substantial part of the flying involved in the early program of hyacinth eradication under Everglades conditions.

ing the overall rate of materials applied. Pressure, dispersal level and the swath flown are other factors in determining dosage. Generally speaking, the volume of material ranges from three to eight quarts per acre in droplet sizes of 150 to 200 microns.

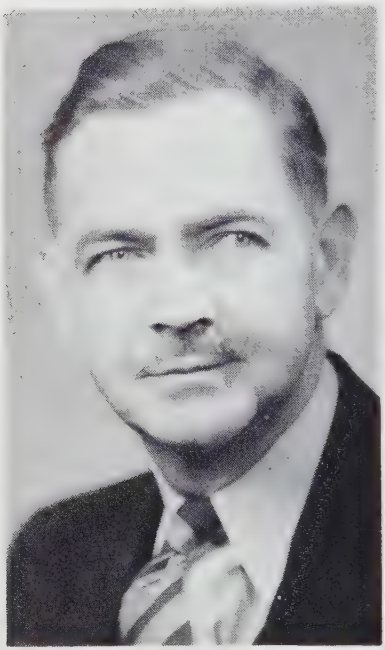
The helicopter is considered unconventional but very effective in its operation. Its advantages include slow and variable rate of travel plus accessibility to some areas considered hazardous and impractical for conventional craft. Its disadvantage lies chiefly in its cost and maintenance.

In order not to overlook the original equipment for aerial application of herbicides mention must be made of the familiar duster planes which were used extensively in some areas to apply 2, 4-D in dust forms. Too numerous complaints on extensive damage resulted in U. S. D. A.'s recommendation to the Civil Aeronautics Authority to ban this method and means of application. It is believed that leaky hoppers, inefficient hopper doors, and, in many instances, the operator's lack of appreciation of the potency of the material handled, are contributing factors in this decision. However, the principal reason usually given is the too frequent uncontrollable drift.

In conclusion, I might add that effectiveness of any equipment for the type of work under discussion depends largely on the operator—certainly airborne is no exception.

THE EFFECT OF CERTAIN HERBICIDES ON THE WATER HYACINTH AND OTHER AQUATIC PLANTS*

F. W. ZUR BURG**



DR. F. W. ZUR BURG

Dr. E. J. Kraus of the University of Chicago is generally credited with having discovered the herbicidal properties of certain auxins in the year 1941. The first published work appeared in *Science* in 1944. This publication and subsequent work gave clear indications that a new and powerful weapon, useful in the control of noxious weeds, had been discovered.

The work on which this report is based was done in three phases: First, in the early spring of 1945 the writer, co-operating with Dean T. J. Arceneaux and Prof. Ira Nelson of the College of Agriculture of the Southwestern Louisiana Institute, initiated studies on the use of 2, 4-dichlorophenoxyacetic acid as a phytocide for the control of the water hyacinth. In the second phase, the writer continued these studies in 1946 as a collaborator with the United States Department of Agriculture. In the final phase, the writer acted as consultant with the New Orleans District of the United States Corps of Engineers.

Prior to 1945, Prof. Nelson had made several attempts to remove the hyacinth cover from a small two acre lake known as Lake Fletcher and located on the Southwestern campus. Mr. Nelson attempted crude mechanical methods first, but this proved unsuccessful. Later, he attempted to destroy the plants by spraying them with fuel oils. This second method also proved to be fruitless since the re-growth appeared to exceed the original stand of plants.

It will be recalled that very little had been published on the herbicidal properties of the phenoxy compounds in 1945. At that time, it was customary for investigators to dissolve 2, 4-D (the parent acid itself) in polyethylene glycol and to prepare the final

*—Presented by R. V. Allison

**—Chemist, Southwestern Louisiana Institute, LaFayette, La.

spray solution by mixing the glycol solution with water in the required amount. Because of this solubility difficulty, the writer first determined to examine the herbicidal properties of various compounds related to 2, 4-D with the hope that some of them would show better water solubility and perhaps better herbicidal activity. Dozens of these compounds were prepared in the laboratories at Southwestern. In the years that have followed that study, most of the compounds prepared have appeared on the market and a great deal of work has been done by many investigators on these commercial products.

Insofar as I can determine, Lake Fletcher was the first sizable body of hyacinth plants to be subjected to 2, 4-D compounds. This work was done early in 1945 and the results of the first work done were highly satisfactory. Because of the age of this first experiment, the lake was carefully watched and no hyacinths have been allowed to bloom on that body of water. The object in watching the lake has been to study the viability of the seed. During 1946 the hyacinths on the lake were allowed to grow but the blooms were hand picked daily. At the end of the 1946 season, about one per cent of the original area was again covered by hyacinths. The 1946 crop was destroyed with 2, 4-D. During this past year; i.e., the 1948 season, about two dozen plants were seen on the lake. From this, it would seem that under the conditions encountered in Lake Fletcher, the seed are not the serious consideration that they have been thought to be by some investigators. Plants of the size originally sprayed on the lake run between three and five hundred thousand to the acre. Thus the hyacinth cover of the lake decreased from about three quarters of a million to a couple of dozen in the period mentioned.

A number of things were learned that first year. For example, it was found that "tub tests" and green house tests did not always give the same results as did field tests. Just what caused these differences was not determined. It might be the fertility of the water or the oxygen tension of the water. I feel sure that there is a difference in glass filtered sunlight and that of the open field.

But during the winter, the greenhouse tests did give us indications and did prepare for the following year. During the 1946 season, the writer had the good fortune to work under the direction of Mr. W. L. Kephart of the U.S.D.A. Rather elaborate plans were made to decide just what was to be done and how the experiments were to be carried out, but I shall proceed to describe the work of that season and to give some of the results.

For one thing: a difference had been noted in the herbicidal activity of the water soluble salts of 2, 4-D and the oil soluble esters and parent acid. It was first decided to contrast the wetting properties of the carrier oil in the oil emulsion ester sprays with the straight aqueous solutions of the 2, 4-D salts to which wetting agents were added. For these tests a spray solution having a concentration of 1000 parts per million of 2,

4-D acid or its equivalent as an ester or salt was used. To make the tests more uniform, spray applications were made at the rate of 200 gallons per acre.

Arbitrarily, the butyl ester was taken for a standard since, in oil emulsion, this compound was known to have good herbicidal properties. The average of several tests indicated that when this material was used, good epinasty resulted at the end of about 24 hours and that at the end of eight weeks the recovery or re-growth was about 2 per cent. It might be mentioned at this time that some herbicides give good immediate results, or apparently give an immediate kill; yet, when the plants are examined it is found that the rhizomes have not been affected. Of course, the final results of such a herbicide are worthless. It is believed that a great many erroneous reports have found their way into print because the results have been read too soon. Thus, the eight week period was taken as the minimum final time of final reading and most results have been watched for four months.

Contrasting with the butyl ester, the sodium salt in the above mentioned concentration and quantity was used. It was found that when the salt and water *alone* were used that there was only slight epinasty at the end of 24 hours and that there was about a thirty per cent recovery at the end of eight weeks.

Next, a series of tests were made by adding various surface activators or wetting agents to the solutions of the sodium salt. About three dozen or more commercial wetting agents were tested. This list includes soda ash, soap, sodium salts of sulfonated petroleum hydrocarbons, sodium lauryl sulfate, mannitan monolaurate and many others. The soda ash increased the ability of the water to film the surfaces of the hyacinth leaves but did not appreciably increase the kill. With about three pounds of soap per hundred gallons the epinasty was better at the end of one day and the kill was slightly better at the end of eight weeks. A great many commercial wetting agents gave excellent results. Among them might be mentioned the Atlas' Company's "NNO," Monsanto's "Aresket 300," Rohm and Hass' "Triton K-100," du Pont's "IN-181-P" and Atlantic Refining Company's "Ultrawet."

It will be noted that in subsequent tests the wetting agent "Ultrawet" has been used rather extensively. This does not mean that it necessarily gives the best results, but rather that it gives an excellent herbicidal solution when acting as a wetting agent with the sodium salt and that it is relatively cheap and that only a small quantity is required.

It was found that the use of excessive amounts of the surface activators caused the herbicidal solution to drain too rapidly from the leaves and that a small amount did not give good wetting nor materially increase the kill. By trial and error, it was found that Ultrawet is best used in a concentration of from six to eight ounces per hundred gallons of 1000 p.p.m. sodium salt spray solution.

During the 1946 season, attempts were made to determine the length of time necessary for the hyacinth to absorb a lethal dose of 2, 4-D. It is obvious that such studies were necessary since a rain following a spray application would tend to wash the herbicide from the plant leaves.

An early set of experiments was carried out in thirty gallon wooden tubs. Each tub contained a dozen or more healthy water hyacinth plants, and the water in each tub contained about two teaspoonfuls of concentrated fertilizer.

In each experiment the hyacinth plants were removed from the water and inverted. While in this inverted position the plants were thoroughly sprayed with the particular herbicidal formulation being worked with. After various intervals of time, the inverted plants were thoroughly washed with large amounts of water. The amounts of water used corresponded to an almost impossible weather situation, since in terms of rainfall the wash water would be about six inches of rain per hour.

It was observed that time of contact required for almost all oil emulsions was practically zero. It is safe to say that five minutes of contact was sufficient in the tub experiments. This, it is believed, is due to the fact that it is almost impossible for a fresh water wash to remove completely the oil film from the leaves. In a field test, a plot was sprayed with an oil emulsion of an ester during a light rain. Practically a hundred per cent kill resulted. In another test, a quarter acre plot was sprayed with 100 gallons of the butyl ester of 2, 4-D in oil. The concentration as 2, 4-D acid equivalent of the solution was 0.1 per cent. Within twenty minutes after the spraying was completed, the plot was washed by the heavy rain of a thunder shower. Apparently, there was no marked difference in the amount of kill obtained in this plot and the kill obtained under dry conditions.

In the tub tests, when water solutions of the sodium salt were used as the herbicidal spray, the contact time appeared to be about ten minutes. That is, some plants were killed after a five minute exposure, whereas some required as much as fifteen minutes. When wetting agents were added to these aqueous sprays, the average time required was about five minutes.

In a field test, a quarter of an acre of hyacinths was sprayed with 100 gallons of the sodium salt of 2, 4-D having an acid equivalent concentration of 0.1 per cent. This amount of solution contained six ounces of Ultrawet as a surface activator. The spraying was followed in about 45 minutes by a drenching rain. At the end of eight weeks the per cent kill was only about 40 or 50 per cent.

It is believed that oil emulsions of 2, 4-D may be used during light rains and still retain their herbicidal activity. Straight aqueous solutions probably should not be used if rain is anticipated within a few hours, or perhaps if cumulus clouds are forming and turning dark.

From the view point of the U. S. Corps of Engineers, it

would be desirable to have an herbicide that would not only kill the hyacinth, but it would be still more desirable to have a material that would destroy the plant and cause it to sink rather rapidly in the water. The Engineers are particularly interested in this since their main objective is to open waters to navigation and the dead plants offer practically the same hazard to navigation as do the live plants.

In 1946, methods of bringing about the accelerated sinking of the hyacinth plants were worked on. At first, it was thought that by increasing the fertility of the water the organisms which bring about the decomposition of the plants might be stimulated. Repeated tests gave no hope for this method. The waters were fertilized with large and small amounts of commercial fertilizers and with variations in the nitrogen, phosphorus, potash ratio. Barnyard manure was also applied to the dead plants with negative results.

A few other things were done in 1946. For example, dyes were added to the spray solutions. With such solutions it was hoped that the plants could be marked so that the spray operator might easily see the results of his work. Some of the purple dyes gave good desults, but when the amount of dye used was considered and the cost of this dye was added to the cost of the solution, it was decided that the use of dyes on a large scale was not feasible.

One fact might be mentioned in connection with the desirability of marking the work of the spray operator. It was noticed that the wetting agents (or the carrier oil in the ester sprays) served as a marking agent. The leaves of the hyacinth are so completely wetted that they reflect considerable incident light. Thus, the wet leaves stand out in contrast with the leaves remaining unsprayed. As for an inspector checking on the work of a spray rig operator—if a good 2, 4-D formulation is used the inspector need only wait 48 hours before making his check and he can then most certainly tell by the epinasty of the plants where the operator was lax in his application.

During the summer of 1947, the writer was privileged to work as a consultant with the New Orleans district of the U.S. Corps of Engineers and to be associated in this work with Mr. W. E. Wunderlich whose work on mechanical destruction is well known.

One of the things attempted in this season was to continue the work on "sinking agents." I might mention that between 1946 and 1947 a great many water hyacinth experts developed in Louisiana and that 2, 4-D was discovered and re-discovered at least fifty times. We also developed a number of "sinking experts" during that period. When some of these claims were investigated, it was found that "sinking" as defined by the new expert consisted of the sinking of the plants to the water level and not a total submergence.

One of the interesting "sinking agents" developed in this

period was Schweitzer's Reagent. The writer does not doubt that this reagent will dissolve the cellulose of the water hyacinth since this is the notable chemical characteristic of cuprammonium hydroxide. But, considerable amounts of the reagent would have to be used per acre and the material is expensive. It is also true that soluble copper is very toxic to both plant and animal life. Of course, we were trying to use a material that was relatively non-toxic to fish and other aquatic life. For this reason, the writer did not use Schweitzer's Reagent except in tub experiments.

Remembering that the paper and pulp industries have settled on certain chemical reagents for the separation of cellulose and the lignin binder in the production of their product, it was thought that some of the agents might be of use in breaking up the water hyacinth plant. As a result, 2, 4-D solutions containing various amounts of caustic soda were tried both for herbicidal action and as a "sinking agent."

To briefly summarize the results: It was found that the caustic digested the waxy surface of the leaves and stems and allowed subsequent rotting to proceed more rapidly. It is not believed that caustic solutions of less than 1 per cent NaOH by weight have very much effect but that solutions of caustic in which the alkali content is between one and three per cent are fairly satisfactory as a decomposition accelerator or "sinking agent." For example, when a plot was treated with a solution consisting of 1000 p.p.m. of the sodium salt of 2, 4-D and 2.5 per cent sodium hydroxide, over half the plants submerged and sank within 40 days. This is a considerable improvement over the normal period of months. The writer believes that this is not necessarily the answer, but that continued studies along this line should be made. Reagents other than caustic soda might be used.

As for the toxicity of caustic soda to fish: It is not necessary to apply more of the solution than that amount required to wet the leaves of the plants. The digesting action is almost immediate and can be observed. After exposure to the atmosphere, the caustic is soon converted to the carbonate. This compound, if allowed to get into the water, does not appear to bother the aquatic life.

Further attempts were made to activate the water soluble 2, 4-D salts and to bring them to the herbicidal activity of the oil soluble esters. It was observed on small plot operations that the addition of mineral acids to 2, 4-D solutions appeared to increase the activity of the herbicides. Jones mentions this fact in his patent. By trial and error, it was found that the addition of about four or five ounces of sulfuric acid to 100 gallons of spray solution containing 1000 p.p.m. of the sodium salt gave excellent results.

It might be said that the addition of the acid to the sodium salt of 2, 4-D simply forms the parent acid of 2, 4-D and this is

true. It might be argued that the solution should be made with 2, 4-D itself and then less acid would be required and this is also true. But, the 2, 4-D acid is hard to dissolve in water whereas the sodium salt can be dissolved with ease; thus, it is easier for the operator to start with the salt and to waste a small amount of acid.

In all cases when five or six ounces of sulfuric acid were added to the 100 gallons of 0.1 per cent 2, 4-D sodium salt solution to which a few ounces of Ultrawet had been added, the percentage kill was noticeably better; in fact, such spray solutions are as effective as the oil emulsion ester formulations and are much cheaper.

It might be well to add a few words about droplet or particle size of the sprayed solutions. During 1947 we tried various types of sprays to determine effectiveness of each. At first, it seemed to make little difference as to whether we used a solid, heavy stream of the herbicidal solution or a fine fog. With plants of moderate size there is probably no difference. However, when the treated plants were very high; that is, over three feet in height, the fog sprays did not work as well. Apparently, the fine fog can not penetrate into the depths of the heavy vegetative growth.

Of course, small droplets do not settle as fast as large drops and with fogs more wind drift may be expected. The Louisiana Conservation Department had some unfortunate trouble with wind drift of dusts of small particle size. In some of our experiments with small drop sizes, using aqueous sprays, we noticed damage to adjacent vegetation even when the utmost care was used to eliminate or control the drift.

A lot of other things were done. The list of known herbicides, organic and inorganic, were again tested. Mixtures of various herbicides were tried. But, the story is long and the results, in most cases were unsatisfactory.

The effect of herbicides on alligator weed was also considered. As is known, 2, 4-D will easily control this pest when it grows on land, but the same phytocide is unsatisfactory when this plant is growing in water. However, a fair control of alligator weed was obtained by making heavy applications of emulsifiable ortho dichlorobenzene. Also, some hope was given by two experiments in which an emulsifiable mixture of carbon tetrachloride and oil, containing 2, 4-D was used as the spray solution. This emulsion is heavier than water and settles. It will be admitted that both of these treatments are harmful to aquatic fauna.

To summarize, perhaps a few comments and a few personal opinions should be expressed. We all know that the hyacinth problem is big and that vast areas are concerned; but we also know that immeasurable benefits would follow the elimination—or perhaps, I should say—the control of this weed. We might start with the cost of materials. In many cases we have been paying too much for our equivalent 2, 4-D.

In order to whip the hyacinth problem in Louisiana, perfect co-ordination of known mechanical and chemical methods will probably be required. It is not intended that the two methods should be contrasted; for, they are each adaptable to entirely different situations. The saw boats can not get close into shore and therefore always leave a fringe to re-infect the streams. At the same time, it is almost impossible to drag heavy spray equipment through the hyacinth jams without first having a way cleared by the saw boats, and certainly no chemical can open the streams as rapidly as the saw boats can at the present time.

Mention has been made of the fact that the hyacinth has been practically eliminated on a small lake on the Southwestern campus. But this was just a two acre plot. Near Lake Arthur Louisiana, we practically eliminated the hyacinth over a vast area. In this area, the waters flow in both directions. That is, the flow depends on whether the gulf or the swamps are exerting the greater water head.

The writer believes that we have got to use chemicals if we want to accomplish any permanent good. Let us suppose that it would cost as much to chemically spray an area as it costs to mechanically saw the same area. The mechanical process must be repeated year in and year out and the cost remains constant. But with the chemical method the cost decreases each year and would eventually disappear.

It is a big problem, but I am sure "it can be done."

THE CONTROL OF AQUATIC WEEDS BY CHEMICAL METHODS IN THE FLORIDA EVERGLADES

CHARLES C. SEALE*

INTRODUCTION

Since the first tests on the Hillsboro canal during the late spring of 1945 with 2, 4-D a considerable amount of experimental work has been done on the determination of suitable chemical methods for the control of water hyacinths and other aquatic weeds by several persons and agencies in the State of Florida.

The Jacksonville office of the U. S. Army Engineers, War Department under the direction of Colonel Teale has made a thorough investigation of the extent of the infestation of the waterways of Florida with the more important water weeds, and has sponsored an extensive program of experimental work for the eradication of these pests. In a certain phase of this work, Evans (3), working out of that office, gave cooperative assistance to the project.

The systematic eradication of water hyacinths in the Florida Everglades was commenced in 1946 by the Everglades Drainage District. This work, largely by air spray, proved so successful that it was later extended to include a large scale control of these pests in the principal arterial canals of this area. Johnson (5) has given the Board of Commissioners of the Everglades Drainage District a comprehensive report of the scope of this work and the results obtained during the period 1946 to 1948 (See Appendix, pp. 212-219)

Hilderbrand (4) experimented in 1945 with 2, 4-D for the control of water hyacinths, as we now also learn did Dr. F. W. zur Burg (7) and his associates in Louisiana during the same year through the paper he has given on this Symposium.

During the period under review a considerable amount of experimental work also was done by Allison and Seale (1) at the Everglades Experiment Station on the control of water weeds.

From November 1945 until June 1948 particular attention was paid to the control of water hyacinths, *Eichornia crassipes* Solms. More recently, however, and especially since the successful removal of larger quantities of water hyacinths from the drainage system of the Florida Everglades as a result of the untiring efforts of the Everglades Drainage District, work has been commenced on the control of other aquatic plants, both of the submerged and emergent types, which tend to take the place of water hyacinths. Many of these plants already have clearly demonstrated their ability to become very serious pests, and it

*—Associate Agronomist, Everglades Experiment Station, Belle Glade, Florida.

seems likely that the working out of suitable methods for their control may be more difficult than in the case of the water hyacinth. In the initial stages of this more recent work by the Everglades Experiment Station, special attention has been focused on chemical methods for the control of certain submerged types of aquatic plants such as *Najas* sp., *Ceratophyllum* sp. and *Anacharis* sp. very common water weeds which produce dense growths in many of our canals and farm ditches.

In this paper is presented an outline of experiments with chemical methods for the control of water hyacinths, and some preliminary findings of work recently commenced on certain submerged aquatic plants.

THE CONTROL OF WATER HYACINTHS

Description of Plant

The water hyacinth, *Eichornia crassipes* Solms., is a member of the pickerel weed family, *Pontederiaceae*. This plant is generally found growing in areas of fresh water such as ponds, lakes, canals, streams and rivers. It can tolerate somewhat brackish water, but is not very winter hardy. In the Everglades area, plants grow very vigorously and attain frequently a height of 50 inches, and a density of 200,000 per acre.

Propagation generally occurs vegetatively by means of stolons, but a few plants are also produced from seed, when suitable conditions exist. The young plants have bladder-like petioles which are their principal means of flotation, but as they grow older the petioles become slender. As the plants continue to grow to maturity they develop rhizomes which may be as long as 10 inches.

Distribution of Hyacinths in Florida

A recent survey conducted by the War Department, U. S. Army Engineers, indicates that Florida is the major area of infestation in the Southeastern section of the United States and that about 63,000 acres in the State are now infested with this obnoxious pest. The areas of greatest infestation are the Kissimmee, St. Johns and Withlacoochee rivers, which account for about 60 percent of the total area involved.*

An extensive program of eradication by the Everglades Drainage Board has now considerably reduced the incidence of this pest in the principal arterial canals of the Everglades drainage system, but the plant is still very prevalent in the smaller canals and farm ditches of this area.

Benefits to Be Obtained From the Control of Water Hyacinths

In the flat agricultural lands of the Florida Everglades,

*—Reported on in detail in this same volume of the Proceedings, pp. 21-28, by J. A. Hammack.

where the elevation rarely exceeds 16 feet above sea level, the most important benefits to be obtained from the control of water hyacinths are improved conditions for flood control, drainage and irrigation.

Flood damage caused by hurricanes in South Florida has been very great during the past two seasons, and any means of reducing this hazard is of paramount importance to the agricultural interests in this area. Furthermore, any improvement in facilities for the removal of flood waters will obviously also benefit the normal practices of drainage and irrigation.

It has been estimated by Clayton and Neller (2) that dense growths of hyacinths in the main canals of the Florida Everglades are capable of reducing the discharge capacity by about 50 percent, and also that the transpiration rate from such a cover will be about three to four times the evaporation rate from open water surfaces. The former condition severely impedes drainage, and the latter causes heavy losses of water during the dry season when irrigation is sometimes practiced.*

The presence of large masses of water hyacinths have very harmful effects on fish and wildlife, and the removal of the plants would greatly increase productivity from these sources.**

Many of our lakes and streams have high potential values as places of recreation for fishing, boating and swimming, if they were freed from undesirable aquatic weeds. Also the large scale removal of the plant would greatly facilitate commercial navigation, and would reduce the cost of water treatment for public use and malarial prevention.

Methods of Control With 2, 4-D

(1) *Earlier Experimental Work*

During 1946, a considerable amount of experimental work was done with 2, 4-D for the control of water hyacinths. Allison and Seale (1) presented the results of several tests made by the Everglades Experiment Station, and Evans (3) reported on hyacinth control investigations performed in cooperation with the War Department, U. S. Army Engineers.

In these early tests comparisons were made between spraying and dusting, and the latter method was found to be uneconomical and impractical under Everglades conditions even before it was outlawed by the Federal government.

Different chemical forms of 2, 4-D also were applied at rates ranging from 0.4 to 6.0 pounds of 2.4-D acid equivalent per acre in aqueous sprays of high gallonage, that is 100 to 200 gallons per acre.

The chemical types of 2, 4-D used in these tests included the

*—These relationships reported on in detail by D. B. Bogart, pp. 32-52 this same volume of the Proceedings.

**—These relationships reported on in detail by J. J. Lynch, pp. 58-65 of this same volume of the Proceedings.

inorganic salts (sodium, ammonium and potassium), the esters (butyl, isopropyl, methyl and ethyl) and the amine salts (triethanolamine and alkanolamine).

The results obtained from these earlier tests indicated that the esters and amine salts produced somewhat stronger effects than the inorganic salts of 2, 4-D, and that good herbicidal results were obtained from the application of 1.3 to 1.6 pounds of 2, 4-D acid equivalent in the form of the ester or amine salt.

The above mentioned experiments with 2, 4-D applied by ground spraying equipment in aqueous solutions were followed by trials involving the application of 2, 4-D by airplane at the low gallonage rate of about two gallons per acre. These trials indicated the desirability of using the oil miscible ester instead of the water soluble amine salts.

This latter method proved very satisfactory, and as a result large scale control operations for the removal of water hyacinths from the arterial canal system of the Everglades were initiated by the Everglades Drainage Board.

At the present time a large quantity of the hyacinths have been removed from many of the principal arterial canals in this area, and a method of patrol by boat has recently been set up to take care of remaining fringes along the banks of the canals.

(2) *More Recent Work*:

From the middle of 1947 until the present time a great deal of attention has been paid to the application of 2, 4-D at the low gallonage rate of approximately six gallons per acre by ground spraying equipment, and much of this work has been carried out with equipment loaned to this Station or especially constructed by the staff of the Agricultural Engineering Division of the Everglades Experiment Station. This method of spraying has many advantages over the more conventional type of high gallonage spray equipment.

The most important of these are the much lower initial cost of the equipment, its lightness of handling and the greater economy in the time and cost of applying the spray materials.

Attention also has been given to a comparison of herbicidal effects of these low gallonage sprays with those of higher rates of application.

In March 1947, an experiment was laid out which was designed to test the effects of applying 2, 4-D in the form of the butyl ester at rates ranging from 2 to 200 gallons per acre.

Four weeks after spraying, representative samples of hyacinth plants were removed from the plots in order to determine the effects of treatments on the growing points and rhizomes of the hyacinth plants.

The results of this experiment are presented in Table I from which the following conclusions can be drawn:

(1) the low gallonage oil sprays were far superior to the higher gallonage aqueous sprays.

TABLE I—Results of Spray Tests

Rate Application of Diluent		1 lb. 2, 4-D Acid per acre		2 lbs. 2, 4-D Acid per acre	
Water Gals. p.a.	Oil Gals. p.a.	% Growing Points Dead	% Rhizomes Decomposing	% Growing Points Dead	% Rhizomes Decomposing
-----	2	94.0	88.0	100.0	98.2
25	--	92.7	78.2	98.4	91.8
50	--	86.5	71.2	96.8	90.5
100	--	86.3	60.8	98.2	83.9
150	--	85.4	68.8	96.7	83.6
200	--	86.3	70.6	94.6	82.1

(2) with the aqueous sprays, better results were obtained when the rate of application was 25-50 gallons per acre than when it was 100-200 gallons per acre.

On the basis of this and many other results subsequently obtained from numerous trials, we consider that the most effective control of water hyacinths can be obtained by spraying either by airplane or ground equipment with an ester of 2, 4-D at the rate of 1.0 to 1.5 pounds of the acid equivalent in No. 2 diesel oil at approximately two to six gallons per acre.

THE CONTROL OF CERTAIN SUBMERGED AQUATIC PLANTS

Type of Plants Used in the Experiments

In the initial stages of this most recent phase of the experimental work on the control of submerged aquatics, which is being carried out by the Everglades Experiment Station, two types of plants namely, *Najas* sp. and *Ceratophyllum* sp., were selected for detailed study. These plants are commonly found making dense growths in the canals and farm ditches of the Everglades region of Florida.

Chemicals Used In the Treatments

The herbicidal effects of the following chemicals were compared in our tests:

(1) a chlorinated benzene
(2) seven different types of solvent napthas
(3) hexachloroethane dissolved in a special type of oil derived from coal tar and diluted (1:1) with No. 2 diesel oil.

The solvent napthas used in the tests had the following range of physical properties:

Flash Point	90-250° F.
Mixed Aniline Point	51-135° F.
Kauri-Butanol Value	100-118 ml.
A.S.T.M. Distillation	
Initial Boiling Point	276-425° F.
50% Point	282-504° F.
95% Point	286-614° F.
Final Boiling Point	302-740° F.

Experimental Procedure

During the early part of September 1948 small scale experiments were laid out in the greenhouse at the Everglades Experiment Station. In these tests plant material of *Najas guadalupensis* (Spreng.) Morong and *Ceratophyllum demersum* L., were placed in water-filled glass containers and were treated with the chlorinated benzene, the solvent napthas and the hexachloroethane mixture at concentrations of 100 and 200 ppm.

An emulsifying agent, Triton x-100, was added to all the treatments involving the use of the solvent napthas and the hexachloroethane mixture at the rate of five percent by volume. The results of these tests are dealt with in the following section.

At about the same time two experiments were laid out on a heavy mixed growth of *Najas* sp. and *Ceratophyllum* sp. in a canal located in the Clewiston area to test the herbicidal effects of the above chemicals under actual field conditions. Very unfortunately, however, all of the experimental plots were completely destroyed by the flood conditions which accompanied the hurricane of September 20-21, 1948, and it was decided that no further attempts should be made to set out field trials until the hurricane season had passed.

Results

The results of the greenhouse tests indicate that several of the solvent napthas, with added emulsifier, showed considerable signs of promise, and gave results that were practically as good as that of the chlorinated benzene for the range of values tested. It should be noted, however, that when the emulsifier was not added to the solvent napthas as indicated very poor results were generally obtained.

The hexachloroethane mixture did not give as good results as the other types of chemicals. The manner in which the hexachloroethane was used in these tests was suggested by a commercial supplier, but it may be possible to improve its effects by altering the method of application.

Chlorinated benzene formulations have commonly been used in the past for the destruction of growths of submerged aquatic plants. However, the recent work of Moran and Shaw (6) has demonstrated that solvent napthas also have a strong phytocidal action on certain water weeds.

No definite price quotation appears to be available yet for the solvent napthas, but indications are that their cost will be considerably less than the chlorinated benzene products. Consequently the use of the solvent napthas for the control of submerged aquatic weeds may prove to be both satisfactory and economical.

In the determination of the treatment effects in our greenhouse tests, particular attention was paid to the following conditions:

(1) the length of time taken for the treated plant material to sink to the bottom of the containers.
(2) the commencement of decomposition of the dead plant material and the rate at which it progressed to the final stage.

Quite obviously more attention was paid to conditions (2) above than to (1).

It is thought that the method of small scale testing in the greenhouse previously outlined could be utilized advantageously for a rapid evaluation of a large number of herbicides intended for use in the control of certain submerged aquatic weeds. After the best herbicides had been screened out in the pot tests, then this lesser quantity of good materials could be included in large scale field tests, which would be considered as the source of more conclusive results.

Summary

(1) The work which has been done during the period 1945 to 1948 for the control of water hyacinths and other aquatic weeds by several persons and agencies in the State of Florida is reviewed.

(2) A method for the control of water hyacinths, based on several years of experimental work, is presented. This method involves the spraying of the plants, either by airplane or ground equipment, with an ester of 2, 4-D at the rate of 1.0 to 1.5 pounds of 2, 4-D acid equivalent in No. 2 diesel oil at approximately two to six gallons per acre.

(3) Since the large scale removal of the water hyacinths from many of the arterial canals of the Florida Everglades by the Everglades Drainage District, other aquatic plants have clearly demonstrated their ability to become obnoxious pests. Consequently particular attention is now being paid by the Everglades Experiment Station to methods of control for the submerged aquatic weeds, *Najas* sp. and *Ceratophyllum* sp. Preliminary results of pot tests indicate that certain solvent napthas gave a satisfactory control of these plants. This control was practically as good as that obtained with a chlorinated benzene product.

(4) The work on submerged aquatic weeds at the Everglades Experiment Station is being continued.

Acknowledgments

Grateful acknowledgment is made to Dr. R. V. Allison, Vice Director, Everglades Experiment Station, for very helpful advice and assistance rendered during the investigation.

The writer is also indebted to Mr. John W. Randolph and Mr. William A. Desnoyers (deceased) of the Agricultural Engineering Division of the Everglades Experiment Station for assisting

with the construction and use of the spray equipment in some of the more recent phases of this work.

The cooperation of the following companies in supplying the various chemicals used in these tests is greatly appreciated: American Chemical and Paint Co., Ambler, Pennsylvania; R. J. Brown Co., St. Louis, Missouri; Chipman Chemical Co., Bound Brook, New Jersey; The Dow Chemical Co., Midland, Michigan; E. I. DuPont de Nemours Co., Wilmington, Delaware; Esso Standard Oil Co., New York, New York; Fine Organics Inc., New York, New York; Pennsylvania Salt Manuf. Co., Philadelphia, Pennsylvania; The Sherwin-Williams Co., Chicago, Illinois; Standard Agricultural Chemicals Inc., Hoboken, New Jersey; The United States Rubber Co., New York, New York; Wilson Spraying and Supply Co. Inc., West Palm Beach, Florida.

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CONTROL OF SUBMERGED AND EMERGED WEEDS IN THE FEEDER CANAL OF THE WEST PALM BEACH WATER SUPPLY SYSTEM

RUDOLPH P. TOMASELLO*

This is a report of a chemical weed control project conducted in the West Palm Beach Water Company's canal for the control of submerged and emerged aquatic plants that were impeding the water flow. This canal was dug to drain water from the Loxahatchee slough into Lake Mangonia which serves as the reservoir for the West Palm Beach Water Company.

While chemical control of submerged aquatic weeds in irrigation systems in the West has been in use for some time, and has also been used in this State, there are still many factors in the use of chemicals for this purpose that are not too well understood.

There were many species of aquatic plants in the canal but the most prolific and troublesome plants were Eelgrass (Vallisneria americana), the White Water Lily (Nymphaea odorata) and the Yellow Water Lily (Nephar advena).

It was suggested by several authorities that two applications would be necessary because of the density of the weed growth. In this case it proved to be correct.

At the time of the first application, the canal averaged about thirty feet across and its greatest depth was about four feet. The water level was extremely low and a static water condition existed. Certain portions of the canal were completely choked by the weed growth, so much so that we found it necessary to put men on each bank to pull, with ropes, the rowboat that held the sprayer. A spray boom was used that reached from shore to shore. The even pull of the men on the opposite shores kept the boat in the middle of the canal, making for a uniform application.

A gear-type pump was used but in order to develop greater pressure this was supplemented by a plunger-type. The plunger-type pump became inoperative very soon because the chemical used destroyed the plungers and packing. It was necessary to use Neoprene hose as the chemical caused disintegration of natural rubber.

The material used for the first application was Benoclor-3, which was found to have certain disadvantages. This material is very hard to emulsify, requiring pressure up to 200 pounds for good emulsification, and even after emulsification it had a tendency to break and settle quickly to the bottom of the canal.

The average spray pressure used was about 30 pounds. It appeared that the best results were obtained when the Benoclor stayed in suspension and in contact with the weeds the longest

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time. The best nozzle position was found to be just under the water, as a better emulsion and distribution of the chemical was obtained in this position. When the nozzles were lifted clear of the water, little if any of the material would emulsify and it formed clear liquid drops that fell to the bottom of the canal.

Benoclor is caustic to the skin and when emulsified with water it is even more so. One operator stepped into treated water and was burned severely. The symptoms were of a severe sunburn, the skin peeling, causing much personal discomfort.

Starting at the head of the canal we worked slowly downstream. We treated 13,800 feet of the canal which carried us to the first control gate. 200 gallons of Benoclor-3 were used. The chemical seemed to work very slowly and after two weeks the kill appeared very disappointing, though some of the weeds were breaking loose from the canal bottom and forming floating masses of dead plants. It became apparent that the chemical was still active when bare feet and hands were burned slightly when a worker waded into the water to secure a soil sample from the canal bottom for analysis.

At this time an airboat was used in an attempt to break loose the dying weeds from the canal bottom. Eight half inch chains fifteen feet long were placed at the stern of the boat acting as streamers. The airboat moved back and forth over the canal many times to do this job. This procedure was beneficial and it was soon apparent that the chemical was more effective than it had appeared at first. The dragging seemed to stir up the Benoclor and it killed weeds not affected by the initial application. Since the Benoclor-3 did not stay in suspension for long and since there was little if any current, no weeds were killed beyond the treated area.

At the time the submerged weeds were being treated with the spray boom under water, the water lilies were sprayed over the top with a hand gun. This method of applying Benoclor to the lilies was of little value as only a temporary leaf burn developed and several weeks after the application, the burned leaves were scarcely noticeable. Neither method of treatment appeared to be of much value in killing the water lilies, at least not at the time. However, later the lilies in the middle of the canal started to disappear, opening up a passage for a boat. It was thought that this was probably due to a combination of the chemical and the dragging.

We had been led to believe that inasmuch as the game fish were very active, they would move out of the treated water into the lake and would not be affected by the treatment, whereas the sluggish Garfish would remain in the treated water and would be destroyed. The results were not exactly as predicted. Large numbers of Bass and other game fish were destroyed while a smaller percentage of the Gars were killed. Many water Moccasins and soft shell turtles were also destroyed. The fish began to die very soon after the treatment and continued for

several days. These fish floated to the top of the water and were removed with dip nets and seines by a crew of men.

About a month after the first treatment a second application was made. This time Benoclor-3C was used and appeared to be superior to Benoclor-3. During the interval between the first and second spraying, daily rains had raised the canal level about one foot and there was considerable water flowing. The canal had by this time widened and the boom was not sufficiently long to reach from bank to bank. However, we expected the chemical to disperse and in the fast moving current cover the entire water area. Where the canal bottom was very shallow for three or four feet out from the shore, there was little current and the chemical did not cover this area thoroughly. There was a noticeable line along the canal bottom between the treated area and the portion that the spray did not reach.

Benoclor-3C emulsified in the water much better and stayed in suspension much longer than did Benoclor-3. As a result of this a much more rapid and superior weed kill was obtained. It was estimated that about 80 per cent of the weeds were killed by the two treatments, the submerged weeds being much better controlled than the lilies. Due to rapid flowing water, weeds were killed for more than a mile below the point where the spraying stopped. The second spraying covered the same area as the first spraying. There was a much greater volume of water in the canal at the time of the second spraying and though we applied 25 gallons less material at this application, the results obtained from the Benoclor-3C were superior in every respect.

Benoclor-3C also was destructive to game fish and was more destructive to the Garfish than the Benoclor 3. It was interesting to note that fish life was quickly reestablished. Only one week after the last application large Bass were being caught in large numbers and two weeks after the application, we saw one man with a string of fourteen Bass taken from the treated area. Now, several months after the treatment, the canal is again stocked with fish that have come in from the lake, the sloughs and ponds. It is the opinion of many keen observers of fish life that after the high water which is now present recedes, the fish will be as abundant in the canal as they were before the treatment.

It appears that an annual application of Benoclor 3C will give a satisfactory control of aquatic weeds, at least for the submerged weeds that now are found in this canal.

SOME WATER QUALITY RELATIONSHIPS OBSERVED UNDER EVERGLADES CONDITIONS IN THE COURSE OF STUDIES OF POSSIBLE AFTER EFFECTS FOLLOWING HYACINTH TREATMENT WITH 2, 4-D

T. C. Erwin*

With the cooperation of the U. S. Fish and Wild Life Service a study was inaugurated to determine the effect of hyacinth eradication with 2, 4-D on the fish life of the Everglades, and to determine the cause of frequent fish kills observed in these canals.

Methods used in this study were chemical analysis of the water (dissolved oxygen, oxygen demand, hydrogen sulphide and pH), comparative fish trapping, and live fish boxes.

It has been shown that the 2, 4-D used to kill the hyacinths will have no toxic effect on fish when used in any reasonable quantity. The question to be answered here is: what is the effect of the decaying hyacinths and the effect of their removal?

It was found that during the summer months the water in the canals is generally unsuited for normal fish life. This is true except for regions near the lake when there is a large flow of good water coming from the lake into the canals. The canal water is usually very low in dissolved oxygen, and has a high oxygen demand, and at times has a high hydrogen sulfide content. No doubt there are a number of other reduced gases which occur in the water along with H_2S which have toxic effects on fish. During this summer the dissolved oxygen in one canal at one sampling point about six miles from the lake was always below the level considered necessary for normal fish life and at times could not be detected at all. The H_2S content of some canal samples was greater than 30 p.p.m., 10 p.p.m. of H_2S in water is considered very toxic to fish.

Careful observations and comparative trapping indicate that during the time of this study (June to November) the only aquatic life in the canals at a considerable distance from the lake (over four miles) consisted of turtles, gars, salamanders (Siren Lacertina), and top minnows. These salamanders were quite numerous and some of the specimens trapped were two feet long.

However, the population of the smaller drainage ditches in the farms was quite different. In the spring the aquatic population consisted of bass, brim, catfish, suckers, gar, and top minnows. As the summer rains began and the water from the soil was drained into these ditches the fish life began to suffer. First the bass population started to decline and after each heavy rain dead fish were observed floating in the canals.

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This year on the first day of November there was an unusually heavy rain which put the finishing touches on what the summer rains had been doing. After this heavy rain the only apparent survivors in the farm ditches were gar and top minnows. Since then the top minnow population has been increasing rapidly.

We can surmise a broad picture of the whole situation something like this: the lake is the main area of survival during the summer months when the canals are contaminated with toxic soil water. As this condition improves the fish move out into the canal system to feed on the accumulated population of top minnows, where many are trapped in the farm ditches and killed by the toxic water during the summer.

When water stands under hyacinth mats for any length of time the water will not be suitable for normal fish life. Therefore, the fish tend to move to the farm ditches which are kept free from hyacinths. Fish will inhabit the canals under hyacinths when there is a flow of water from the lake. As a matter of fact they are very quick to follow good water to new areas in search of food. This can be seen by the fact that if, when the lake is higher than the canals, a lock is open for a short time and then closed again, dead and sick fish will begin to appear on the surface of the canal. If at this time the lock is cracked to allow only a very slight flow of water, fish can be observed concentrated at this crack and passing through it back into the lake.

It has also been observed that when the canals are draining into the lake fish will leave the rim canal and the shore waters of the lake. During these times fish may be caught in the middle of the lake but not around the edge where the contaminated water of high oxygen demand is entering.

Studies of ground water indicate that it is very low in dissolved oxygen and high in oxygen demand but not as high in H_2S as some of the canal water samples. This brought up the question of where the H_2S was coming from. Some could be accounted for by the action of anaerobic bacteria in the soil; however, it was hard to see how such a concentration as 30 p.p.m. could be developed. Quite by accident in the course of a soils experiment it was discovered that when muck soil ash is mixed with raw muck soil and water a considerable quantity of H_2S is liberated. This led to the conclusion that when muck soil burns sulfides are formed due to the limited oxygen supply. Further investigations showed that ash from very old muck fires when mixed with a little acid would not liberate H_2S; however, relatively new ash would. The action of water leaching through this ash can account for the occasional occurrence of high levels of H_2S in the canal water. The slow decomposition of the muck soil will account for the low dissolved oxygen of the soil water.

On October 9, 1946, a test was made of the H_2S content of

TABLE 1

Hydrogen Sulfide Content of the Canal Bordering the Rear of the Everglades Experiment Station

Date 1946	Notes	ppm H_2S
September 30	Shortly after a heavy rain	40
October 1	With no further rain	18
October 2	With no further rain	15
October 4	With no further rain	2
October 8	After rain of October 7	29

the water in the rim canal that encircles Lake Okeechobee. It was found to be 7.2 p.p.m.

Conclusions

(1) The water under live hyacinth mats is not suited for normal fish life except where rapid flow from a good water source will maintain the necessary water quality.

(2) During the summer months the canal water will become toxic to fish even in open surfaces.

(3) The toxicity of the water is caused by the action of water on muck soil and is due to low levels of dissolved oxygen, high oxygen demand, and the presence of other toxic substances such as H_2S.

(4) The action of decaying hyacinths during the summer months will not cause fish kill as normally there will be no fish, which would be affected by their decomposition, under these hyacinths. That is to say, the condition of the water at times is so unsuitable for fish life that the decaying hyacinths could not make it worse.

DISCUSSION

Led By

LAMAR JOHNSON*

and

B. A. BOURNE**

The discussion was initiated by Mr. Lamar Johnson, Chief Engineer, Everglades Drainage District, with a statement in reference to the report that had recently been prepared by the District to cover two years of hyacinth eradication work on the arterial canal system of the Everglades District. This report is to be found in full in the Appendix of this volume of the Proceedings beginning on Page 149.

Many questions were raised regarding the details of hyacinth and other water weed control which were largely answered in the several papers already presented in the symposium. On this account the discussion pertaining thereto will not be repeated here.

More discussion was raised in regard to the control of Para grass on ditch banks, and particularly where it extends into ditches or out into the water area from the banks of larger canals, than on any other subject. It was generally agreed that this is one of our most difficult pests to control, and reference was made to the work of Mr. B. E. Lawton, County Agent in Broward County, where a considerable degree of success has been achieved with the use of sodium chlorate on the mineral soils of that section of the Everglades.

In commenting on the work with sodium chlorate, Mr. Charles C. Seale called attention to the very considerable danger of fire with this compound. Whereas good results have been reported on mineral soils through the use of 160 pounds of chlorate per acre, very poor results were obtained on muck soils through the use of this and even greater amounts. Mr. Seale also reported in a very preliminary way on the use of ammonium trichloracetate on this pest by stating that he had been able to kill the rootstock with applications varying from 100 to 200 pounds of the chemical per acre depending to some extent on soil conditions. He also reported that very little work had been done to date with this chemical where the Para grass had passed out onto the water surface of larger canals from its rooted position on the bank.

Dr. B. A. Bourne, of the U. S. Sugar Corporation, Clewiston, raised the all important question of cost by citing the fact that treatment of a mile of canal 32 feet wide with 175 gallons of

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benechlor cost $400.00, while that for a 16 foot canal infested with nigger wool was $115.00 per mile. Lamar Johnson called attention to the fact that the Everglades District's costs were all in the report referred to above and which is to be found in the Appendix of this volume, Pages 149-159.

Dr. Bourne also called attention to the relation of weed population in the canals and farm ditches to rate of silting, and called attention to the fact that this alone would justify the weed control operation. Attention also was called to the economy of mopping up operations following the first kill in contrast to allowing practically full recurrence and thus necessitating the cost of the full treatment again.

With reference to the cost of treatment, Mr. L. S. Evans brought much encouragement into the discussion by calling attention to the fact that, while some of the newer napthas that are proving so effective against water weeds are required in about the same amount as the benoclor compounds, the cost at the present time, still at a preliminary level, is only a fraction of the latter, i.e. about 20c per gallon against $3.00 to $3.50 per gallon. Mr. C. H. Anderson, of Esso Oil Company, New York, stated that until we know exactly what naptha formulations are best to use, more about freight rates and have some idea of the volume needed in various sections of the country, an appreciable amount of uncertainty in the price shall doubtless continue.

Dr. Bourne closed the discussion by advising that he had no further comment and with the remark that "we are a lot wiser than we were before the meeting."

SYMPOSIUM II.

THE OVERALL WATER CONTROL PROGRAM FOR SOUTH FLORIDA

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A BRIEF REVIEW OF THE WATER CONTROL PROGRAM AS IT HAS DEVELOPED DURING THE PAST SIX YEARS

LAMAR JOHNSON*

Reclamation of the Florida Everglades may be divided into three periods. First, the period from 1907 to 1931 during which time the present canal system was constructed and reclamation evolved from a visionary dream to a tangible actuality. Second, the period from 1931 to 1942 when Everglades Drainage District, the agency charged with the responsibility of reclaiming the Everglades, wallowed in the doldrums of debt and litigation and all improvement and maintenance of the arterial canal system stopped. However, it was during this period that the levee around Lake Okeechobee was built, an item that contributed much to the present extent of development by subdrainage districts and private interests. Third, the period from 1942 to the present, during which general recognition was given to the multiple problems other than drainage and efforts were directed toward the development of a plan of water control that would insure maximum utilization of both soil and water.

The first formal recognition of the need of such a plan was expressed in a resolution of the Soil Science Society of Florida in meeting in West Palm Beach, Florida, on April 21, 1942. At its meeting the following year, in Belle Glade, Florida, the Society adopted a resolution urging Everglades Drainage District to assume responsibility for an over-all policy and plan and to coordinate the activities of all governmental agencies in the execution of such plan.

These resolutions were timely. Two Federal agencies, the Soil Conservation Service of the Department of Agriculture and the U. S. Geological Survey of the Department of Interior, were then engaged in programs of investigations and surveys in the Everglades area. The program of the Soil Conservation Service, conducted in cooperation with the University of Florida, Agricultural Experiment Station, included a soil survey of the Everglades and recommendations for water control. The program of the U. S. Geological Survey included both surface and sub-surface investigations and was conducted in cooperation with Dade County and Everglades Drainage District. The work of these two Federal Agencies during this period supplied the basic facts upon which a plan of general water control could be developed.

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The resolutions of the Soil Science Society were timely in that for the first time in many years Everglades Drainage District, having quieted its financial troubles, was free to consider its physical works and the requirements of the landowners. It was obvious that the first responsibility of the District was to determine the future policy and plan for the conservation and development of the land and water resources of the Everglades. About a week after the Soil Science Society meeting in Belle Glade, the Board of Commissioners of Everglades Drainage District, at a public meeting held in Miami on March 26, 1943, arranged a meeting in Tallahassee, Florida, on the date of April 14, 1943.

This meeting was attended by State officials and representatives of State and Federal agencies engaged in Everglades reclamation and its problems. The meeting resulted in agreement on the need for a comprehensive plan to prevent the waste of soil and water resources, and agreement that Everglades Drainage District serve as the authority in the preparation and execution of such a plan and program.

As the first step in determining the future policy and plan for water control in the Everglades, the Board of Commissioners of Everglades Drainage District, on August 13, 1943, authorized the organization of an Advisory Committee comprised of sixteen persons recognized as authorities in various problems of the Everglades. The work of this Committee resulted in a published report dated May 1, 1944.

This Committee's report recognized the fact that not all peat soils in the 'Glades were suitable for agricultural development. It stressed the fact that the present canal system, even if completed to designed cross-section, was inadequate to serve even the reduced area of potentially agricultural soils. For the first time a report of this kind recommended developing large areas of Everglades wild lands for conservation purposes. While pointing the way toward the development of a plan of water control, finances were not available to prepare a detailed plan for the Everglades.

Early in 1945, Everglades Drainage District released a report prepared by W. Turner Wallis, then Engineer for the district. This report briefly recommended certain improvements to the water control system, estimated the cost of such improvements and discussed financing under existing legislative authority. In response to notice of hearings before the U. S. Engineers, in Belle Glade, Florida, in April, 1946 and in June, 1947, the District submitted reports making specific recommendations for the improvement of the major canal system of the Everglades. These latter reports were complete with regard to size and quantities of the items of construction recommended and as to their operation after construction under conditions of both drainage and irrigation.

In 1945, the Soil Conservation Service of the United States

Department of Agriculture, working in cooperation with the University of Florida, Agricultural Experiment Station, released an interim report on soils and water control in the Everglades Drainage District. This report was released in printed form, including accompanying maps, in March, 1948.

These plans of improvement recommended by Everglades Drainage District and the Soil Conservation Service are very similar, reflecting the close coordination of effort in analyzing the data assembled in previous years of research and survey, and in the recommendations for a feasible solution of the many problems. Many of the recommendations of these reports are now recognized as being basic to the protection and development of southeast Florida of the future.

As a result of the many hearings and conferences during 1946 and 1947, the District Office of the U. S. Engineers in Jacksonville, Florida, began the preparation of a comprehensive report on flood and water control for the Everglades and southeast coastal areas. Given impetus by the disastrous flood of 1947, the report was completed during that year and its scope enlarged to include the Kissimmee and St. John's valleys. This report was considered by Congress during its 1948 session and the first phase involving expenditures of $70,000,000 was approved and appropriation of $16,300,000 authorized. Later, Mr. Harold Scott will give you the details of this plan.

For years Florida has wasted soil and water resources with the reckless abandon of the pioneer, without plan or purpose for the future. Today we have a Federal approved plan covering one-fifth of the State's area. The purposeful attitude of the people was evident at the hearings before the U. S. Engineers and before the Congressional committees. We know that Florida is blessed with abundant rainfall and arable soils which if utilized to their fullest extent will assure its future as an agricultural state. At last we are beginning to realize the true value of these resources. We have come a long way in the last six years.

SOME IMPORTANT GEOLOGIC PROBLEMS TO BE ENCOUNTERED IN THE DEVELOPMENT OF A FULLY EFFECTIVE WATER CONTROL PROGRAM FOR SOUTH FLORIDA

NEVIN D. HOY*

Inasmuch as no formal manuscript has been provided to cover the above subject, it will be reported only very briefly in the usual manner.

In preparation for the interesting and informative discussion which Mr. Hoy gave on the relationship between the geology of the area and an effective water control program for South Florida as it shall have to be recognized and worked with from the engineering standpoint, numerous rock samples, maps and a complete geologic cross section extending from Ocala to Florida City were brought into view.

With the geologic cross section showing the inter-relationship of the natural formations of rock, each with the other, and actual samples of Miami Oolite and Tamiami limestone as background material, Mr. Hoy emphasized and reemphasized in about every possible way the very great importance of giving the fullest possible consideration to the extremely high porosity of such substrate materials in relation to any impoundings of surface waters that are to be made over them—at least made in a theoretical way— for the porosity of rocks such as these is said to approximate that of washed gravel.

A map also was shown which outlined the location and extent of the marl, muck and other surface and sub-surface conditions. Attention also was called to the fact that water passes through marl very slowly and that the Fort Thompson formation, which is largely the foundation rock of the Upper Glades, has a comparatively low permeability. In contrast, the Anastasia and Miami Oolite formations both have a very high permeability, whereas Tamiami rock was said to be the most permeable known.

The close relationship of these geologic conditions in South Florida to the problems of water control, soil conservation and salt water intrusion in relation to the safety of the domestic water supply was clearly shown in every respect and left little room for doubt as to the seriousness of the engineering problems that are created by natural geologic conditions to be found in the sub-surface conditions of South Florida's geologic setup. We can find no particular comfort furthermore, in the knowledge that each day, in nature's own, slow way, these conditions are getting worse rather than improving.

In view of the fact that a considerable amount of the infor-

*—Acting Geologist, U. S. Geological Survey, Miami, Florida.

mation reviewed by Mr. Hoy has been published in earlier volumes of the Proceedings of the Society any reader who is interested to that extent is respectfully referred to the following items: (1) Evans and Allison (Soils of the Everglades), Vol. IV-A, pp. 34-46 (1942); (2) Parker (Geology and groundwater conditions), Vol IV-A, pp. 47-76 (1942); (3) Ferguson (Surface water studies), Vol. IV-A, pp. 77-85, (1942); (4) Ferguson (Surface water studies), Vol. V-A, pp. 18-23, (1943); (5) Parker, Hoy and Stevens (Geological studies), pp. 33-94, (1943); (6) Gallatin and Henderson (Progress of soil survey), Vol. V-A, pp. 95-104, (1943); (7) Bogart (Surface water relationships), Vol. VIII, pp. 60-71, (1946-7); (8) Parker (Municipal water supply), pp. 72-88, (1946-7).

As among the above references, Figures 6 and 7, pages 69 and 70 of Proceedings Volume V-A, are of particular interest in showing the extremely porous nature of the supporting limerock in the lower reaches of the Everglades, a point that has come up repeatedly in the discussion of the hydrologic problems of that area. It is obviously one that must be given more and more careful consideration in working out the details of the overall plan of water control for South Florida if it is to serve that area effectively in the future. At least that is the emphases that Mr. Hoy seemed to give it in the course of his review of the subject. —*Editor.*

THE CENTRAL AND SOUTHERN FLORIDA PROJECT

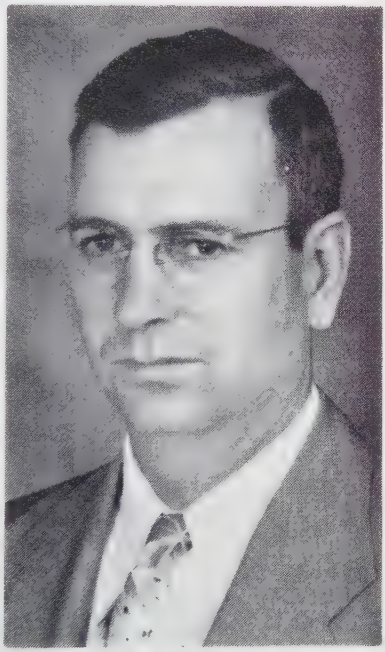
HAROLD A. SCOTT*

The people of Florida have within their grasp the greatest single achievement since the establishment of statehood, namely, the Comprehensive Plan of Improvement for Central and Southern Florida. This plan when completed will relieve large areas from the ravages of floods and droughts and bring untold benefits.

I would like to briefly describe the main features of the plan for the benefit of the few who may not be familiar with it.

General area.—Flood control and water control improvements are proposed in central and southern Florida south of a line extending from the east coast through Lake Harney and Orlando, and along the westerly limits of the Kissimmee River basin as shown on Figure 1.

The area has been divided in-



HAROLD A. SCOTT

MALBEE RUSSELL SCOTT

Ed. Note: Following the close of the meetings in Clewiston on Saturday, Oct. 13th, shortly after noon, it became known that while Mr. Scott was in attendance upon them his wife had gone to the hospital in Jacksonville to await the arrival of the big bird with the long legs and a great deal of knowhow. Up to the time he left Clewiston early afternoon there had been no further news nor was there any by the time he had arrived at Reservation Headquarters, St. Lucie Locks. However, by the time he arrived in Stuart a long distance telephone call revealed that a son had "weighed in" at 3:07 P.M., tipping the beam at 7 pounds, 7 and 1/3 ounces; and that is the reason Malbee Russell Scott is tucked away down in the corner—so his dad can keep an eye on him from here on out; and perhaps recall, betimes, how difficult it was to keep his mind on soil and water conservation, unified plans and all that sort down in the Everglades when his mind and heart so definitely were in Jacksonville at such a time.

*—Head, Multiple Purpose Report Section, Corps of Engineers, Jacksonville, Fla.

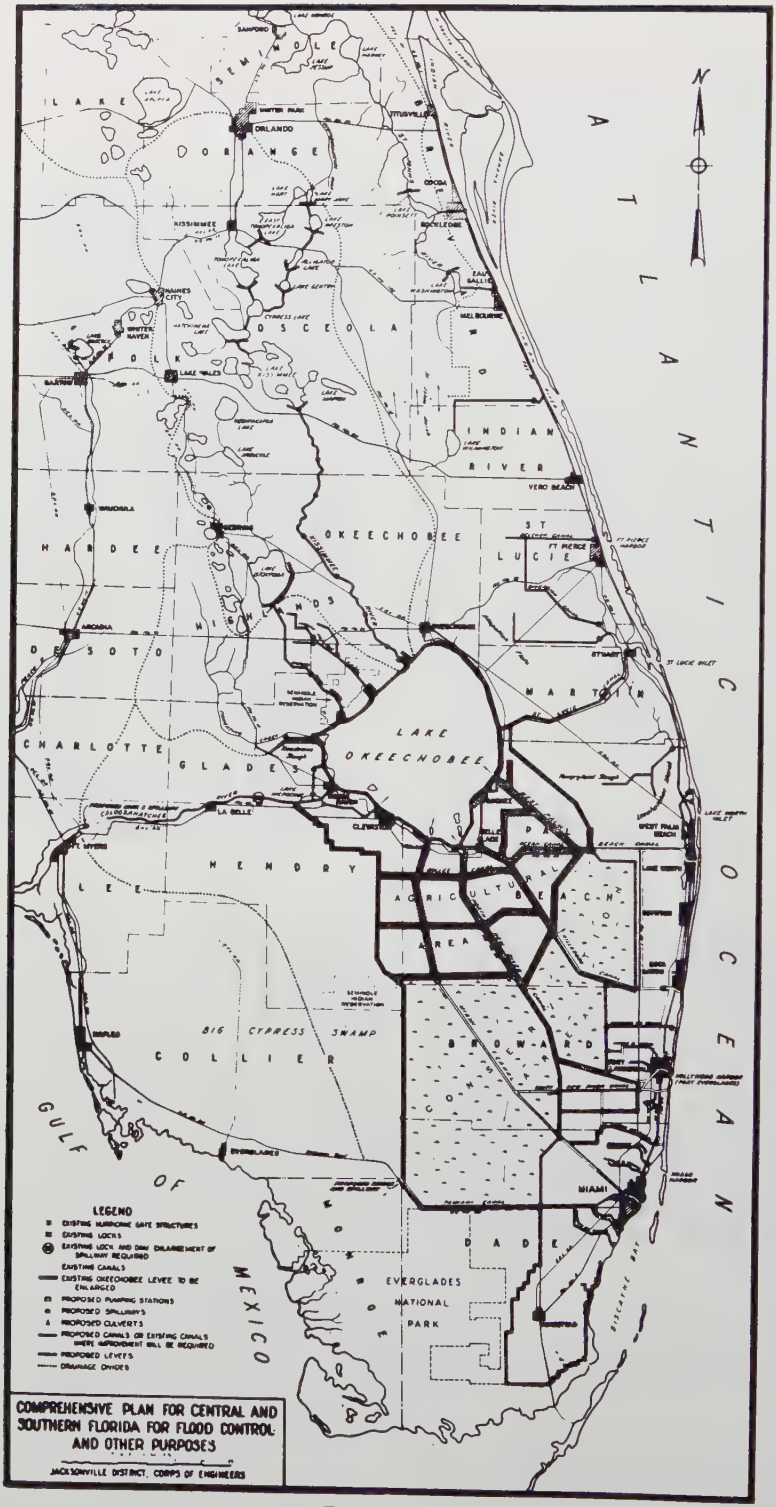

ATLANTIC OCEAN
GULF OF MEXICO
LAKE OKEECHOBEE
EVERGLADES NATIONAL PARK
BIG CYPRESS SWAMP
ORLANDO
MIAMI
OKEECHOBEE
INDIAN RIVER
ST LUCIE
MARTIN
PALM BEACH
BROWARD
DADE
COLLIER
LEE
HENDRY
GLADES
CHARLOTTE
DE SOTO
HARDEE
HIGHLANDS
POLK
OSCEOLA
ORANGE
SEMINOLE
LAKE
LEGEND
EXISTING HURRICANE GATE STRUCTURES
EXISTING LOCKS
EXISTING LOCK AND DAM ENLARGEMENT OR SPILLWAY REQUIRED
EXISTING CANALS
EXISTING OKEECHOBEE LEVEE TO BE ENLARGED
PROPOSED PUMPING STATIONS
PROPOSED SPILLWAYS
PROPOSED CULVERTS
PROPOSED LEVEES
DRAINAGE DIKES
COMPREHENSIVE PLAN FOR CENTRAL AND SOUTHERN FLORIDA FOR FLOOD CONTROL AND OTHER PURPOSES
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS

Figure 1.

to four more or less natural basins for study. The St. Johns River basin includes the area from Lake Harney south to the north Martin County line. The Kissimmee River basin area also includes the Fisheating Creek basin. The Lake Okeechobee-Everglades area includes Lake Okeechobee, the St. Lucie Canal, and Caloosahatchee Canal and River, and about 1,000 square miles of rich agricultural area south and east of the lake. The east coast area includes the coastal ridge in Palm Beach, Broward, and Dade Counties, and about 1,500 square miles of Everglades set aside for water-conservation purposes.

St. Johns River basin.—Any change in the regimen of flow of the St. Johns River must necessarily have varied effects on the surrounding areas which could be made beneficial by careful study, and which also could be detrimental if carelessly undertaken. The rich Indian River fruit area lying along the Indian River derives its water supply and a goodly share of frost protection from the St. Johns River marshes. Overdrainage of this marsh area would not only affect these valuable considerations, but also the water supplies of the towns along Indian River; therefore, the plan of improvement proposes to maintain these marsh areas at their present limits by providing levees at the northerly outlets of Lake Poinsett and Lake Washington, thereby making use of the natural reservoirs provided by nature. The plan proposes to provide canals from Lake Poinsett, Lake Washington, and Lake Wilmington to Indian River for the discharge only of excess flood waters, thereby reducing the amount and duration of flooding now experienced on the agricultural and pasture lands in this area. These canals would be provided with control structures at the lower end consisting of Tainter gates and a concrete structure. In the same manner, canals would be improved or provided in St. Lucie County to provide relief in the upper marshes from excess flood waters. These canals would consist of Belcher, Diversion and a third canal along the county line between St. Lucie and Martin. These canals would also be provided with adequate spillway and control works.

The Kissimmee River basin.—The Kissimmee River basin and its headwater lakes, including those on the low indeterminate divide between the St. Johns and Kissimmee Rivers, have an area of about 4,400 square miles. This includes the area of the series of lakes north of Lake Istokpoga, Indian Prairie Canal, Fisheating Creek, and Taylor Creek, all of which drain from the north or northwest into Lake Okeechobee. All of the lakes in this basin have a potential use as reservoirs for storage of water during the rainy season to be discharged over the dry season; however, some means must be provided for the disposal of excess flood waters. The most feasible method is by enlarging the existing connecting canals and the Kissimmee River. Any improvement of the Kissimmee River however, must be so planned as to avoid overdrainage of the area between Lake Kissim-

mee and Lake Okeechobee in dry periods. The Comprehensive Plan proposes to provide low levees at the outlets of these natural lakes, with adequate control works for regulation purposes. The Kissimmee River itself would be improved and provided with six low dams with control works across the valley, resulting in a continuous reservoir system between Lake Kissimmee and Lake Okeechobee. The lake and reservoir would permit the retention of water by storage after the flood excess has been discharged. This storage would then be available to increase low water flow during dry seasons. The Indian Prairie area would have existing canals improved and extended to Lake Istokpoga with works to discharge excess flood waters more rapidly, while also maintaining adequate ground water during drought seasons. Fisheating Creek would be provided with an improved canal in the lower basin and a spillway for diversion purposes to reduce the amount of local flooding.

Lake Okeechobee-Everglades area.—a. *Lake Okeechobee.*—In its present status and as considered under the Comprehensive Plan of Improvement, Lake Okeechobee is a multiple-use reservoir with flood control, navigation, and water conservation functions. Its waters are impounded by the present levee system and a measure of control is provided by the existing St. Lucie Canal and improved Caloosahatchee River. The existing levees around the rim of Lake Okeechobee protect seven towns and over 130,000 acres of developed rich agricultural land from direct overflow from the lake. The outlet canals and the lake provide a navigable waterway across Florida. Between elevations of 12.56 and 15.56 feet above mean sea level (the present prescribed limits of regulation) the lake provides storage of 1,320,000 acre-feet of water. This great reservoir and its controls are the heart of any plan for flood control and water conservation in south Florida.

b. *Levees.*—The existing levees around the perimeter of Lake Okeechobee were designed to withstand a hurricane attack even more severe than that of 1928. They served their intended purpose in 1945 and 1947 by withstanding hurricane-driven tides and waves with relatively minor damage and with no danger of over-topping or breaching. Experience gained as a result of the floods and winds of 1947 indicates, however, that if the Comprehensive Plan be adopted, a low levee should be extended around the lake shore from the St. Lucie Canal northward to tie in with the present north shore levee, to protect the development which has taken place in that area since the existing levee project was built. Also, a low levee should be provided along the northwestern shore of the lake from the Kissimmee River to Fisheating Creek to protect pasture lands of the Indian Prairie section from overflow by normal rises and wind tides on the lake. This limited protection along the northwestern shore is adequate for present protection of this area, which is pasture land without urban development. In addition to these extensions,

some modification of existing levees may be found desirable in the light of experience gained during the 1947 storm.

c. *Completion of navigation improvement.*—The authorized 8-foot navigation channel from Stuart to Fort Myers has not yet been provided. At present it is only 6 feet. Enlargement of the St. Lucie Canal and Caloosahatchee River for lake control and modifications of the levee systems for Lake Okeechobee, would result in deepening existing channels for lake-control purposes. This would incidentally provide depths of 8 feet or more in the waterway across Florida and would substantially complete that authorized project. Deepening of the channel in the Caloosahatchee River without control works at its seaward end would aggravate salt-water intrusion and overdrainage during droughts, which are already serious problems in this area. To prevent this, the plan provides for construction of a new lock and spillway on the Caloosahatchee River above Fort Myers.

d. *Everglades area.*—The plan would provide flood protection and water control for 1,027 square miles of developed and potentially productive agricultural land adjoining the southern shore of Lake Okeechobee. Flood protection would be provided by constructing levees around the area and by joining them to the existing Lake Okeechobee levee (figure 2). Water control would be accomplished by the construction of a canal network connected to 8 pumping stations on the perimeter of the system. The network would be formed by improving existing canals within the area and by constructing interconnecting and rim canals. The pumps would dispose of excess run-off within the area by pumping from the canal network either into the lake, or into the conservation area to the south, or both; and would also pump water into the area from Lake Okeechobee when needed during dry seasons. The system would also permit a flood discharge of 7,000 cfs from Lake Okeechobee to the conservation area for aiding the control of Lake Okeechobee. Conservation would be provided by pumping excess run-off from the area into the conservation area.

East coast area.—This area consists of the coastal-ridge section and the eastern portions of the Everglades extending from the north Palm Beach County line to the southern tip of Florida (Figure 2).

a. *Everglades conservation area.*—The plan would create three interconnected reservoir areas totaling about 1,500 square miles which would occupy portions of Dade, Broward, and Palm Beach Counties, and which have been shown by the Soil Conservation Service to be unsuited to agricultural development. The reservoirs would be created by constructing a system of levees from the West Palm Beach Canal southward between the main body of the Everglades and the west edge of the coastal ridge to the Tamiami Trail, westward on the trail to the Collier County line, then northward to tie into the west rim levee of the Everglades agricultural area. Levees along the Hillsboro and

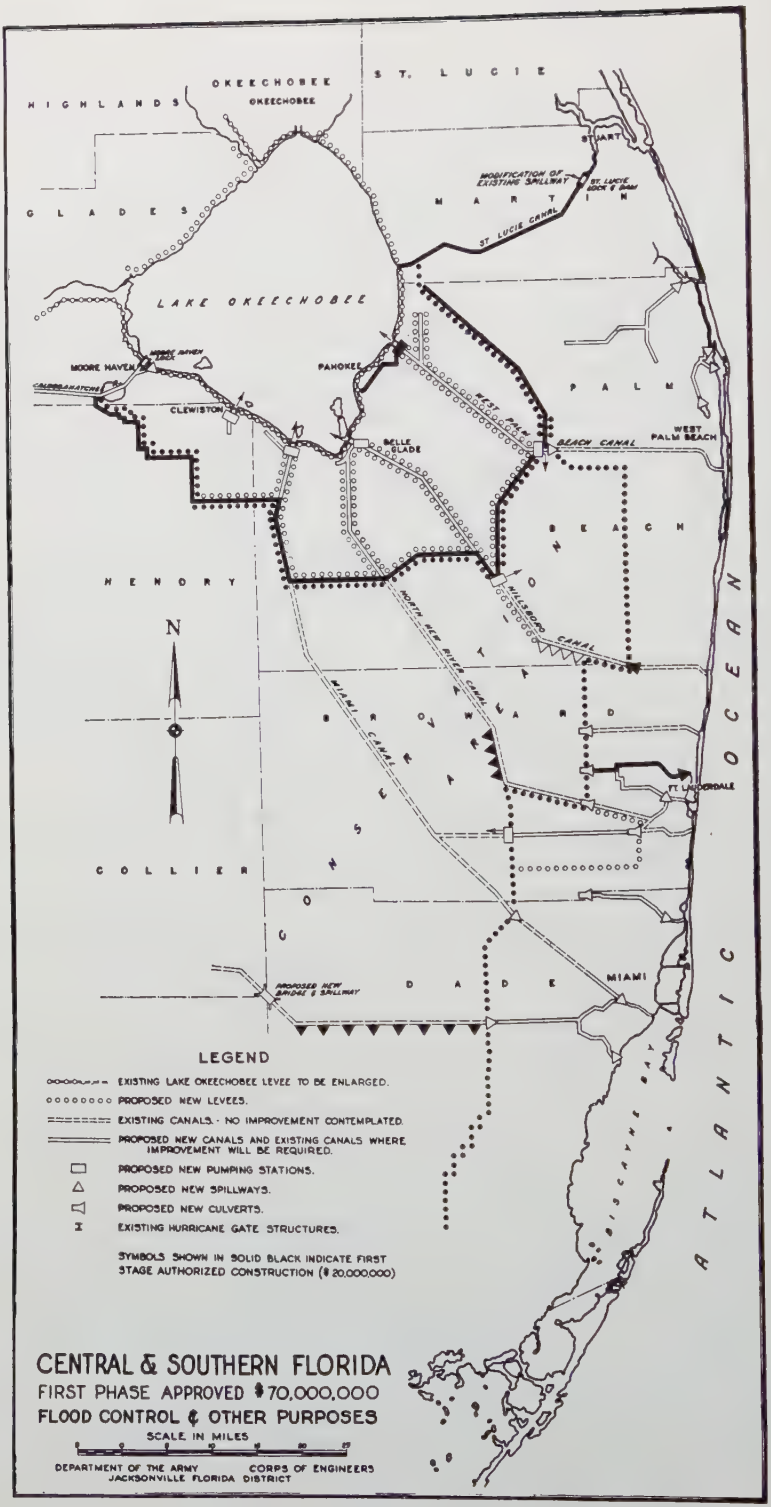

OKEECHOBEE
HIGHLANDS
OKEECHOBEE
ST. LUCIE
GLADES
MARTIN
STUART
MODIFICATION OF EXISTING SPILLWAY
ST. LUCIE LOCK & DAM
ST. LUCIE CANAL
LAKE OKEECHOBEE
MOORE HAVEN
MOORE HAVEN LOCK
CALOOSAHATCHEE
PAHOKEE
CLEWISTON
WEST PALM BEACH CANAL
PALM
BEACH
WEST PALM BEACH
BELLE GLADE
HENDRY
NORTH NEW RIVER CANAL
HILLSBORO CANAL
N
MIAMI CANAL
BROWARD
FT. LAUDERDALE
COLLIER
DADE
MIAMI
PROPOSED NEW SPILLWAY
ATLANTIC OCEAN
BISCAYNE BAY
LEGEND
EXISTING LAKE OKEECHOBEE LEVEE TO BE ENLARGED.
PROPOSED NEW LEVEES.
EXISTING CANALS. - NO IMPROVEMENT CONTEMPLATED.
PROPOSED NEW CANALS AND EXISTING CANALS WHERE IMPROVEMENT WILL BE REQUIRED.
PROPOSED NEW PUMPING STATIONS.
PROPOSED NEW SPILLWAYS.
PROPOSED NEW CULVERTS.
EXISTING HURRICANE GATE STRUCTURES.
SYMBOLS SHOWN IN SOLID BLACK INDICATE FIRST STAGE AUTHORIZED CONSTRUCTION ($ 20,000,000)
CENTRAL & SOUTHERN FLORIDA
FIRST PHASE APPROVED $ 70,000,000
FLOOD CONTROL & OTHER PURPOSES
SCALE IN MILES
DEPARTMENT OF THE ARMY CORPS OF ENGINEERS
JACKSONVILLE FLORIDA DISTRICT

Figure 2.

North New River Canals would divide the conservation reservoir into three parts, interconnected by gated spillways through the levees. These reservoirs would store the maximum-record rainfall on the conservation area plus the run-offs from the area north of West Palm Beach Canal, the Everglades agricultural area, and some flood discharge from Lake Okeechobee. Impoundment of these waters would prevent their flowing eastward as heretofore and flooding the developed areas along the coastal ridge. Maintenance of water in the conservation area would provide water for use on the east-coast agricultural lands when needed, raise the ground-water table, and replenish water supply for the east coast communities, ameliorate salt-water intrusion in the east coast water supply well fields and streams, and benefit fish and wildlife in the Everglades.

Gated spillways in the Tamiami Trail levee would permit discharge of excess water from the conservation area onto low-lying areas to the south, and thence to the lower end of the peninsula. The part of the east coast protection levee which forms the eastern boundary of the conservation area is the major feature for protection of the east coast.

b. *Palm Beach County.*—The planned improvements in Palm Beach County serve various purposes. Flood relief and water control for the Hungryland and Loxahatchee Sloughs would be provided by constructing a canal to the coast with a control structure near its outlet. Flood discharge from Lake Mangonia would be diverted by a canal to Lake Worth. Water control for the Lake Osborne area would be provided by a control at the outlet of the channel at the West Palm Beach Canal, and by a short canal from Lake Osborne to Lake Worth with a control structure at its outlet to prevent salt-water intrusion. Lake Ida would be benefited similarly by a short canal and control structure. Construction of spillways in the conservation levees at the West Palm Beach and Hillsboro Canals would provide water to the entire area when needed during drought periods.

c. *Broward County.*—The plan for improvements in Broward County provides for flood relief, water control, and alleviation of salt-water intrusion. These would be secured by improving and extending the existing Cypress Creek, Middle River, Plantation Road, and Hollywood Canals, and by placing control structures in those canals. Culverts and spillways in the conservation area levees to the west would bring water from the conservation reservoirs to this area by way of Cypress Creek, Middle River, Plantation Road, North New River, and Dania Cut-off Canals for use during dry seasons and for preventing salt-water intrusion.

d. *Davie agricultural area.*—The plan would provide for flood protection and water control for an area of approximately 105 square miles of developed and potentially productive agricultural land west of Dania along the South New River Canal. Flood protection would be provided by constructing and improv-

ing levees around the area; these would be connected to the Broward County conservation area levee on the west. Water control would be provided by improving the South New River Canal and constructing a pumping station at the conservation area levee. The pump would discharge excess water from the Davie area into the conservation area or draw therefrom for use during dry periods. A gated culvert in the canal at State Road 7 would permit flow for water supply and salt-water control in the Dania Cut-off Canal and along the coast.

e. *Dade County.*—The plan of improvement for Dade County would provide for flood control and protection, water control, and alleviation of salt-water encroachment. These benefits would be secured by improving the channels, and constructing control structures at the outlets of the following existing canals:

Miami (in part)	Snake Creek	Coral Gables
Comfort	Biscayne	Snapper Creek
Tamiami	Little River	Black Creek

Gated culverts at the head of Snake Creek, Miami, and Tamiami Canals would provide for the flow of water from the Everglades conservation reservoirs into the area for use during dry seasons. The levee (some 74 miles long) surrounding the agricultural lands of the Perrine-Homestead area would protect against overflow of flood waters from the Everglades and against ocean tides driven by hurricanes from the south and east. Salt barrier-type spillways and gated culverts—13 in all—in the east and south walls of this levee would control the discharge from the canals and prevent salt-water intrusion.

Division of cost.—The total cost of the proposed comprehensive improvement has been divided between the Federal Government and local interests based upon the proportion of benefits to accrue to flood control, navigation, and preservation of fish and wildlife, and benefits from increased use of land. Therefore, it has been deemed appropriate that the Federal Government should pay 85 percent of the total cost of the project, and local interests 15 percent of the project plus the cost of lands and relocations. This breaks down into the Federal share of the construction cost amounting to about $171,041,000 and $749,000 annually for maintenance and operation. Local interests would pay $29,162,000 plus the cost of lands and relocations estimated at $7,942,000 and an annual maintenance cost of $3,034,000.

Construction program.—The Comprehensive Plan is a long-range plan for the control and use of water resources of most of central and southern Florida. It should be initiated at the earliest possible date, as the need for flood protection, water control, and conservation of water is urgent. Now that the plan is approved in part by Congress, future progress in its accomplishment will depend equally on Congressional appropriations for planning and construction and on prompt action by local interests in providing the cooperation required of them.

Assuming, however, that adequate appropriations were made by Congress and that requirements of local cooperation were met, the entire comprehensive development could be completed under an orderly and efficient construction program in 10 years. It is considered, however, that completion of certain parts of the plan should be deferred beyond this period, as the need for such features will depend on progressive development of the areas.

All features set up as parts of the Comprehensive Plan are considered necessary and economically justified. It is practicable now to establish definite priorities for planning of individual items. Some parts of the plan, such as those required for protection of human life and of existing highly developed urban and agricultural areas, are obviously more urgently needed than the longer-range features of the plan. In addition, engineering considerations will require an order of development which would produce, step-by-step, construction of the works which can be operated from the beginning with the greatest efficiency, and which would obtain progressively, from the beginning, the benefits which the plan is designed to produce. The features of the plan are of course subject to some modification of details to make them conform as nearly as practicable to the desires of local interests and to the needs of each particular case.

Conclusions.—The problems of flood control, drainage, and water use in central and southern Florida are complex. They range from protection of life and property from hurricane-driven tides at Lake Okeechobee to maintenance of water levels in dry periods to combat the burning and destruction of muck lands of the Everglades and to maintain the ground-water supply in the lower east coast area. The Comprehensive Plan has been prepared after full consideration of these varied problems. Its preparation has been greatly facilitated by information and requirements furnished by other Federal agencies and by the full cooperation of the local agencies and individuals. The Comprehensive Plan is not a panacea for all the difficulties inherent in the development of this region. No feasible plan of improvement within the realm of economic justification could completely banish flooding of this area, or insure that all needed water supplies would be available during the dryest periods. However, when completed the development would provide a high degree of flood protection and conservation of the water resources of the region. A long-range plan of this kind for flood protection and water control is urgently needed now, so that development of the region can proceed in an orderly manner which will preserve its resources of water and land for future generations. Analysis of economics shows that the project as a whole is justified by a wide margin. Construction and subsequent operation of the comprehensive development to insure that its purposes are obtained would require the best efforts and continued cooperation of Federal, State, and local agencies, but the interest shown

in this plan by the State of Florida and local interests indicates that this can be accomplished.

I know that you are primarily interested in the present status of the comprehensive flood-control project. On June 30, 1948 Congress authorized a flood-control bill containing the following item:

> "The project for Caloosahatchee River and Lake Okeechobee drainage areas, Florida, authorized by the River and Harbor Act of July 3, 1930, as amended, is hereby modified and expanded to include the first phase of the comprehensive plan for flood control and other purposes in central and southern Florida as recommended by the Chief of Engineers in House Document Numbered 643, Eightieth Congress, subject to the conditions of local cooperation prescribed therein, and there is hereby authorized to be appropriated the sum of $16,300,000 for partial accomplishment of said plan."

The first phase referred to in the item refers to work estimated to cost $70,000,000 and covers the area shown on the map. However, as noted in the item, Congress authorized only $16,300,000 which will be supplemented by an additional 15 percent making a total sum of about $20,000,000 available for construction purposes. This work is shown in black on the map of Figure 2.

It is anticipated that Congress will appropriate a small part of the $16,300,000 so that it will become available for advance planning and some construction during the fiscal year 1950. At the present time no funds have been appropriated by the Federal Government to initiate any work on the plan. Prominent local interests, realizing that a year must pass before any work could be initiated, have taken steps to obtain funds for the Corps of Engineers for advance planning work until Federal funds become available. The Corps of Engineers has received a contribution from local interests of $75,000 and an additional $45,000 will be furnished in the immediate future. This advance of money is the first part of local cooperation out of a total of almost $3,000,000 which must be advanced before the Federal Government will begin construction on the first phase of the plan. This money has enabled the Corps of Engineers to initiate field surveys and office studies. Traverse and topographic surveys are in progress in Palm Beach, Broward, and Dade Counties. Core boring will be started within the next few weeks.

It is not known definitely as to how local interests will obtain the full amount of local cooperation necessary to put the plan into effect. Many local interests have discussed various means of how this money might be obtained. The Federal Government considers that it is a problem which must be solved by local interests. No doubt many of you in this room will be called upon to offer services and advice on the various means of making the payment of $3,000,000. Discussions have been had relative to obtaining the money by local taxes, or by the State assuming the

entire burden. It must be realized that while this plan appears to be local, the benefits are State-wide and, in many instances, Nation-wide.

During the planning and construction of the Comprehensive Plan, many difficulties will arise in procuring rights-of-way and spoil areas, and determining the lands which should be used for conservation areas and which lands should be reserved for agricultural endeavors. Many of these difficulties will be settled only after many discussions, arbitration, and some will doubtless find their way into the courts of the State of Florida. Already the District Office in Jacksonville of the Corps of Engineers has received numerous requests for moving the levee locations, canal locations, excluding this land and that land, and taken all together generally rehashing the general alignment of the main features of the plan. These requests have all been answered with the statement that consideration will be given to minor adjustments in the alignments of the various features but the plan as previously conceived is being adhered to.

It is firmly believed that every problem which will arise in connection with the plan can be worked out to a satisfactory conclusion with the help of local interests who own the lands and are directly affected by the project. The most important consideration is that the Comprehensive Plan which was only a dream yesterday is a real and living project today. The Corps of Engineers stands ready to complete the project as rapidly as funds become available so that floods like those of 1947 and 1948 will become only a memory.

OUTSTANDING BENEFITS TO BE DERIVED FROM THE DEVELOPMENT OF A COMPREHENSIVE WATER CONTROL PROGRAM FOR SOUTH FLORIDA

J. E. Beardsley*

The first and, by far, the most outstanding fact to be observed in connection with present efforts at developing a broad, overall water conservation and control program for South Florida is that, for the first time in the history of Everglades development, we have a really effective unanimity of opinion among all interests throughout the area.

I have been here taking it in for 34 years and it is the first time in all of my experience that as many as 3 or 4 have gotten together and, in substance, agreed "Here is something." Granted that the plan may have defects at the present time which, as Mr. Scott has pointed out, are being hashed over from time to time to eliminate at least some of the errors or miscalculations in the original planning, nevertheless, for the first time we have something on which we can agree. Some of you may recall that at the last session of the State Legislature there was quite a unified and agressive effort to abolish the one agency which, in the past, had been attempting to deal, at least in a portion of the territory under discussion (South Florida), with the problem of water control. Reference is to the Board of Commissioners of the Everglades Drainage District.

Now, backed by a combination of powerful circumstances (peak flood conditions), we have an excellent example of what can be done by comprehensive planning in the prevention of such destructive situations. The two needs, prior planning and the prevention of such catastrophic experiences as we have so recently passed through, are now firmly bound together in the public mind and recognition is finally being given throughout the State to the merit of the long time contention that has been argued so strongly in South Florida for many, many years in behalf of a safe and sound overall water control program.

We hope the next session of the Legislature will show recognition of the facts which exist and a willingness to give financial support to the necessary phases of the comprehensive plan. We have recognition even in Washington that the program should be handled as a national as well as a local problem. As the best possible evidence of that fact we have the Chairman of the Subcommittee of the Senate which deals with matters of this nature arriving in the State very shortly for a personal examination of this area and its problems.

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*—Member, Board of Commissioners, Everglades Drainage District, Clewiston.

IMPORTANCE TO AGRICULTURE

Actually the plan will be of little use if it does not adequately concern itself with the welfare and development of agriculture. For Florida is essentially an agricultural state and will find an ever increasing need for growth in this field if the requirements of a rapidly increasing population are to be successfully met.

Sugar Cane

We may have a change of opinion in Washington with respect to the production of sugar, and if that change of opinion comes

Figure 1.—Normal field of sugar cane capable of producing 40 tons of cane at maturity containing 3 to 4 tons of raw sugar per acre.

about, it is ample demonstration of two things: first, that we *can* because we have successfully produced sugar; and second, that sugar cane plant will stand a lot of beating. The evidence is in the fields right now.

It is interesting to recall that the first agricultural development in the Everglades was based on sugar. There is no question whatsoever as to the possibility of expanding sugar operations as we do have the land and the experience as well as the necessary management. We lack two things: first, authorization by the Federal Government to increase sugar production; and second, the physical protection necessary against the very flood conditions which you can see all about in the lake area at the present time. Thus, no one would argue that the conditions shown in Figure 2 are satisfactory for sugar production and that the normal plant growth shown in Figure 1 is not much to be preferred for this purpose.

Figure 2.—Sugar cane under flooded conditions in the Canal Point area which not only had a difficult time keeping off the red side of the ledger but even of surviving.

FIBER CROPS

We are on the verge of a tremendous development of fiber plants in the Everglades, Figure 3. Unfortunately, ramie, one of the most important among them, is particularly susceptible to high water, Figure 4. Moreover, both Sansevieria and kenaf also are quite particular in their needs for water control whether growing on organic soils or the mineral soils adjacent, although not nearly as sensitive as ramie.

The comprehensive plan, which we have heard discussed, when put into operation should provide the necessary degree of protection and a real future for ramie and several other fiber

Figure 3.—Normal growth of ramie on the organic soils of the Everglades. Three cuttings from a stand of this type should yield at least 3/4 ton of dry, decorticated fiber per acre, per year.

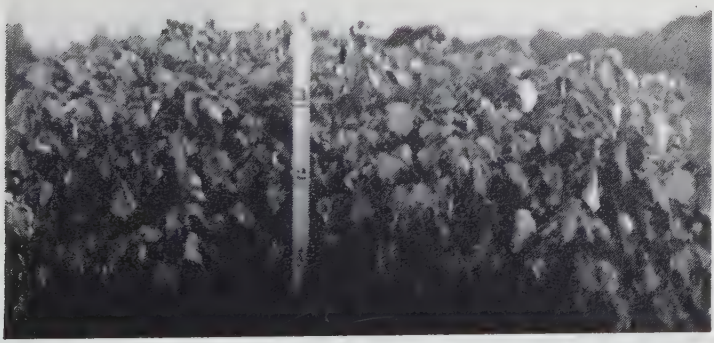


Figure 4.—One of the early plantings of ramie at the Everglades Experiment Station (Autum 1929) showing wilting and loss of leaves during a period of excessive rainfall the following spring as a result of poor drainage. Photo taken June 24, 1930.

crops which are being investigated at the Everglades Experiment Station by State and Federal workers. There seems no question as to possibilities for these crops in this area extending almost beyond the average imagination. However, adequate control must be regarded as a prime prerequisite for the development of these crops.

LIVESTOCK AND PASTURE

Now we come to livestock. There are pastures throughout the Okeechobee and lower Glades area that are completely flooded at this moment. Conditions in the Lake Istokpoga area are much worse than last year and resemble a vast, almost limitless, lake. Only a couple of weeks ago the water was up to the running board of cars right here in the city of Clewiston. As a matter of fact, I am told that was the reason for delaying your meetings which were scheduled to be held here at about that time.

The two most important phases of livestock development which an adequate system of water conservation and control will assure in South Florida are: (1) Production of feeders on what we now call range cattle country to the north and west of Lake Okeechobee; and (2) The finishing of cattle in the upper Everglades. Today neither of the above are risks that any man cares to take even though many are doing it.

However, I am firmly convinced that given that degree of protection against floods, which will also enable the muck soil farmers to produce bumper crops of high quality corn for use in the cattle project, this Everglades Country will be turning out the highest grade of beef to be found anywhere. We've got to keep the grass and grow the grain. We will then make far better annual yields than any state in the south, whether it be corn or finished beef. The contrast of good and bad conditions, insofar as the livestock industry is concerned, is well shown in Figure 5.

Figure 5.—Part of the purebred Devon herd at the Everglades Experiment Station grazing Para grass "in depth." This is a most desirable contrast to the almost complete removal of the cattle population from the Glades proper following such storms as that of 1947. Such forced migrations are very costly in terms of time as well as animal losses. The only answer is *Water Control* and *Conservation.*

VEGETABLE CROPS

Vegetable farming is a gamble with unlimited room for expansion in this section of the State if needed. Aside from reducing and even eliminating some of the risks in this hazardous field, an improved water control system also is going to encourage some of the diversification that we have needed so badly in the agriculture of this section of the State.

OTHER BENEFITS

There are a lot of other benefits of which Mr. Scott has indicated a considerable number. Principal among them is, of course, the protection of the East Coast. Reference in this is not only to such catastrophic floods as have been experienced much too frequently in this area in the past, but also to the continuity of domestic water supplies through critical periods of drought which otherwise develop with about the same regularity as the floods unless the overall protection is developed against both sets of circumstances which Mr. Scott has discussed so ably. In other words, if we don't save water when we happen to have too much we certainly are not going to have it when there is too little, and when we need it badly, in consequence.

The Agricultural Interests and Chambers of Commerce have yet to fully appreciate the fact that the great conservation areas which are being set up in these sections (points to Mr. Scott's maps) with their extensive exposures of water surfaces will go far in restoring the mild winter temperatures that characterized the East Coast areas before the drainage of the Glades began.

Agricultural interests will benefit in this respect along with populous areas because sand land farming operations all up and down the East Coast, including the lower Glades which are very extensive, have suffered tremendously, not only from cold, but also from drought. In my own experience during the past 30 years in the Glades, I can vouch for the noticeably lower average winter temperatures which have been experienced. Incidentally, the State recently acquired an additional area of 50,000 acres for inclusion in this (points to "Hillsboro Lake" tract) conservation area with the proposal that the whole be turned over to the Wild Life Service of the U. S. Department of the Interior with the State retaining the water control rights on it.

A further benefit is to be found, of course, in the value of such conservation areas in the reestablishment of wild life in these sections such as in the so-called "Hillsboro Lake" section.

I can tell you for a fact that possibilities exist out in these areas for development along these lines which not even the wildest-eyed sportsman will believe until he has actually seen them. These natural benefits of the water storage areas contemplated in the plan together with the benefits they confer upon adjacent areas are really something to conjure with in contem-

plating the future possibilities for development in South Florida, agriculturally and in many other ways.

To my way of thinking the most outstanding benefit of this heroic plan to this great section of the State is, in effect, the removal of fear. By this I refer not only to the timidity of the individual coming into a country where such experiences as we have just gone through happen over and over again. Reference also is to the timidity of capital.

The development of this comprehensive plan which we have been discussing this morning will very definitely attract the kind of capital which took a chance when it came in here and built the sugar mill at Canal Point, or the one at Clewiston and the one over at Okeelanta; also the ramie development on the other side of the lake; and the many packing house enterprises in Belle Glade—they all took chances, most of them of a type that ordinary possessors of capital will not think of risking. We can now have real hope of putting development in this section of the State on a basis where much of that fear has been permanently removed. We must bring in the capital and the people that go along with it. To me such an accomplishment will be, by far, the most outstanding benefit of this plan to this area.

There are, of course, other points in the matter of fire hazards and other considerations that go along with Soil Conservation which are of extreme importance to the future development of this section of the State, which must be incorporated into this plan with great thoroughness and care.

In closing, I am impelled to point out that these people who you see working in the Everglades stay in this country because they love it. In fact, they love it so much that they have absorbed the floods, the fires and the winds through the years as matters of course. Certainly they are not the timid sort or they would not be here.

I can also tell you that they are not so calloused to the roughness of the treatment that they have experienced in the past that they will not appreciate the benefits of the plan we have been discussing and the relief from the perpetual fear that everyone feels while living under such conditions. They will not only appreciate these changes, but will take the fullest possible advantage of the benefits conferred by this plan, as it develops, in order to improve the use of the land and give it the better protection that it has needed so long through the physical facilities that, for the first time, will be available for this purpose.

DISCUSSION

Led By

COL. H. G. MATTHEWS*

Col. Matthews: We have had a number of able, as well as some rather blind, discussions on the control of aqueous and sub-aqueous weeds. There also has been a considerable amount of discussion of water control, floods and drought. These tie together very easily, particularly in our flat country.

We must have adequate drainage canals that function efficiently. We are approaching the weed control problem as a means to an end in the water control effort. My job is to see that end arrived at for the State as a whole. We have a subcommittee of congress coming in, the chairman of which is from the Nevada mountains. Senator Malone has no conception of the flatness of this country; it is inconceivable to him that floods can lie on the land for so long. We must get these things across to him.

Water control benefits as they affect the whole State can be illustrated with a few simple facts. The State of Florida was the first portion of the United States discovered by the white man and still only 7 percent of the land of the State is developed after about 400 years. That is one thought. Another general fact is that a dead cow doesn't pay any taxes; a drowned out crop doesn't send kids to college, doesn't pay any bills. We are principally an agricultural State and any community is handicapped by floods. Under such conditions you are not going to have any major developments. People will be sparsely scattered over the area; property evaluations will be low; communication facilities will be developed to only a minimum degree, if they exist at all. Business and professional men in the area are going to be poor. Public health will be bad. In other words, we must get weeds out of the canals, dig more canals, set up proper water control works with proper reservoirs.

The problem is simple but it is going to take unity in this area and over the whole State to solve it. We are beginning to get that unity. We are going to need the help of the whole State to put this job over. Let us set up an arrangement or understanding whereby the rest of the State, in turn, can be helped. In other words, this can be treated as an economic thing which happens only once or we can look ahead a bit and see what we can do to get those benefits from planning to which we are entitled. I should now like to hear some discussion from the floor.

Harold A. Scott: I should like to mention a point here. Those familiar with the work that is going on with the comprehensive plan might wonder if the geological survey by Mr. Hoy, and the map which I submitted, offer a high probability that we may

*—Chief, Division of Water Surveys and Research, Tallahassee, Florida.

run into difficulties. These porous rocks could very easily prove a boon to the comprehensive plan rather than the opposite. Why should we try to improve on nature. We do realize the problem that we are up against and we can provide the answer. The problem can be solved.

Lamar Johnson: The thing that is worrying me is the ability of the rocks to yield water. While they may be quite a boon to that end of the State, I am wondering if you find any differences in the ability of the rock to yield any water, as between the Tamiami limestone and the Miami Oolite, for instance?

Nevin D. Hoy: Geologically they are about the same on the average. This sample of Tamiami is very dense. It is generally uniform.

Horace A. Bestor: There is little public understanding of the resources of the State or any conception of what we are exploiting and wasting. The fertility of Florida soils is negligible for the most part. We must put something into our soils to get full value. The really great advantage is in the climate and in our generous water supply. Water is not alone the problem of flood control. The future of Florida depends on its water supply.

The condition of development that we are in now is relatively a pioneering situation. We seem never fully to have recovered from the storm of 1928. Development results to date all indicate that from the outset we have been largely dependent on water supply. We have already had considerable experience with a small group only in respect to municipal uses. During the development of the increased need of water, we are talking about industrial developments. However, we have no such water supply. The benefits of water are so great and the demand develops so fast and becomes so big that I doubt if there is anything in the way of public understanding.

Matthews: As estimated by the salt water encroachment on the present uses of water, etc., population of Florida would be limited by lack of water at a time when we arrive at about 3 times the present population unless we do something about it.

Bestor: I think that is a very conservative estimate. Nobody realizes what might happen until we reach a critical condition. That phase has not been appreciated. Even though we make mistakes we will learn by doing something consistently.

There is no question as to the hydrological advantages in having water control. We will, by storing and conserving our water, come close to restoring those natural conditions which we have so nearly destroyed. One thing we must remember and that is every drop of water that originates in South Florida that is useful comes from rainfall. There are no outside sources. We cannot do a lot of downhill draining. One only conserves this water by taking advantage of the things that are not going to bleed your land out but will hold your moisture. We can easily do this with the rainfall we have had even with beneficial flood

control heights. Damage is temporary. Put that water to a useful purpose.

R. V. Allison: In all this water storage talk there is a point we must remember. As soon as we begin to store water on a surface with a highly porous substratum we are going to lose that water through simple leakage. That is to say if Tamiami lime rock has the porosity of washed gravel, which the geologists claim it does, then it leaks and leaks badly and we might as well face this fact.

Indeed there are those who hold that the shallowness of the organic mantle to the South and over these areas of highly porous rocks is due to exactly that factor, leakiness. In other words, if your kraut barrel has even one hole in the bottom, you are not going to have a very good volume of kraut after the elapsed period of fermentation. All of this ties in to our overall question of soil losses in all parts of the Everglades wherever these organic soils are drained and tilled; and this brings up the further question as to where our agriculture is going when it has to leave the Glades!!!

While this insidious subsidence tendency can be delayed by the manner in which we handle these soils, we must nevertheless suffer a continuing loss at a rate that is roughly a straight line function of the depth to the water table.

However, the actual discussion of our agricultural outlook against the time the main body of the Everglades becomes nonarable should doubtless better be made the subject of another symposium. In the meantime, we should not forget the hard facts with which we are confronted and even keep in mind that abandoned agricultural areas of marsh soils which have been well fertilized during the period of cultivation are proving to be some of the finest wild life areas in the world. This is largely due, of course, to the great abundance of feed plants resulting from the substantial residue of plant food which has accumulated from the agricultural practices of the past. In the meantime, too, we should exercise every vigilance and spare no effort at improving both soil and water conservation practices in the whole area since the dissipation of the land itself through use can be greatly slowed down by the use of judicious management practices.

Johnson: I read an article a short time ago where agriculture in the West is pumping water from tremendous depths underground for agricultural purposes; and up in Washington Senator Malone only recently made a statement that he had just come from a conference on one of the projects in the West where they were considering pumping 1800 cubic feet per second from a level of 600 feet. We are not in that shape yet. Maybe we've wasted our water but we've pretty well replaced it during the last couple of years. Artesian wells don't rise 20 feet in the air but they can be pumped with a hand pump. It is truly time to do something about our water supply, but we are starting

pretty even with the exception of soil loss. We are much better off now as we still have water. Mr. Hoy, do you have any idea of the rate of salt encroachment along the East Coast?

Hoy: There is practically no salt encroachment in Dade County at the present time. During the past year and one-half canal flow proved sufficient to hold salt water back. Temporary dams also were placed. The experience was that the salt concentration passed from 1000 p.p.m. to 3000 over a period of six months and then moved back to 500. This is an overall value for observational purposes and has remained stationary except in the southern part of Dade County. The West Palm Beach area is still pretty well down. Southeast part of Florida remains about stationary at the present time. Not getting much better but it takes a lot of time.

Hoyt A. Nation: Dr. Allison mentioned it was desirable to have members of Fish and Wild Life Commission present at these meetings. What has the State Board of Health decided concerning spraying of 2, 4-D on these lakes and canals?

Allison: In further reference to my earlier remarks and, in fact, to the makeup of our present program, I do feel that the Fish and Wildlife people should be taking an increasingly active interest in the future development of the Everglades area. With regard to Mr. Nation's question, the Board of Health will now approve the use of 2, 4-D, provided it does not contain free phenol, at least in the amount that we can do the job with. Since there is no free phenol in 2, 4-D, we should have a considerable degree of freedom in its use insofar as toxicity to fish, domestic animals, etc., is concerned.

Johnson: The freedom of this material from toxic principles surely needs some good publicity.

J. E. Beardsley: Called attention to current report in paper of a Government committee of 21 that had been appointed to review the COMPREHENSIVE PLAN and work with local and State boards as well as the Corps of Engineers. There are to be 8 members from the State Legislature and 13 citizens at large. We are fortunate that Senator John Beacham, of West Palm Beach, and Mr. B. Elliott, of Pahokee, are named to that committee. We in the Glades are exceedingly fortunate in that a staff member of the principal metropolitan newspaper of South Florida, a very worthy friend who has done us tremendous service, and who I am happy to say this morning has been nominated to that committee is here, present with us—Jeanne Bellamy.

Shortly following the introduction of Miss Bellamy, Col. Matthews called attention to the lateness of the hour, 12:30 P.M., Saturday morning, and closed the discussion forthwith. A motion for adjournment was made immediately thereafter and, upon favorable voice vote the meeting was formally closed by Chairman Bestor.

BANQUET AND BUSINESS MEETING

The Ninth Annual Banquet was held at the Clewiston Inn on the evening of October 12th, 1948. The Guest Speaker for the occasion was Mr. Lewis S. Evans, Plant Industry Station, U. S. Department of Agriculture, Beltsville, Md. Mr. Evans' address "The National Weed Control Program" is printed in full in this volume on pages 9-14, inclusive.

BUSINESS MEETING

The reading of the minutes of the past meeting was dispensed with and the report of the Secretary and of the Editor were each of an oral nature. The report of the Treasurer, to be made at the close of the calendar year, was ordered audited at the proper time by the following committee: D. W. Smith, Chairman; T. C. Edwin and J. C. Hoffman.

Report of the Nominating Committee

In view of the recent resignation of the Vice President of the Society, Dr. Lewis H. Rogers who had accepted a position with the Oak Ridge Project prior to the meeting, it became necessary to elect a president as well as a Vice President for the coming year and the Nominating Committee was so instructed by the Chair at the time of their appointment early in the meeting.

In making their report, the Committee submitted their choice of Dr. W. T. Forsee, Soil Chemist, at the Everglades Experiment Station Belle Glade, for President and Dr. R. A. Carrigan, Biochemist and Spectroanalyst in the Soils Department of the College of Agriculture, Gainesville, for Vice President. The Chair then called for nominations from the floor. None were offered. A motion was then made and seconded that the Secretary be instructed to cast a unanimous ballot for the slate that had been offered by the Nominating Committee. This action was approved by oral vote with no dissent. The new officials were duly inducted into their respective offices immediately prior to the close of the meeting.

Meeting of the Executive Committee

A very brief meeting of the Executive Committee was held immediately following the close of the business meeting especially to appoint a Secretary-Treasurer and to discuss the dedication of the forthcoming volume of the Proceedings, No. IX, covering the meetings just concluded.

In filling the post of Secretary-Treasurer, R. V. Allison, Everglades Experiment Station, Belle Glade, was again appointed. In respect to the dedication of the Proceedings it was unanimously decided to request of Colonel Willis E. Teale the

privilege of dedicating it to him in recognition of the great and good work he, as District Engineer, and his associates in the Jacksonville District Office, Corps of Engineers, have done during the past few years in the development of a UNIFIED PLAN OF WATER CONTROL AND CONSERVATION for Central and South Florida in close cooperation with State, Federal and local agencies. The Secretary was instructed to contact Colonel Teale and learn his pleasure in this matter.

RESOLUTION OF SYMPATHY

Soil Science Society of Florida

Whereas, death has taken from our rolls during the year the following esteemed members of the Society whose sincere and constructive interest in all aspects of the work will make their absence keenly felt for a long time to come,

Now Therefore, Be It Resolved, that this expression of sorrow over this great loss and of sympathy to the immediate families of the deceased be spread upon the records of this Society and a copy of same be sent to the closest member of the family of each.

Mr. J. C. Adderly
Molino, Florida

Mr. G. J. Barstow
South Bay, Florida

Mr. Rex Beach
Sebring, Florida

Dr. Charles E. Bell
Gainesville, Florida

Dr. William J. Buck
Belle Glade, Florida

Mr. Joshua C. Chase
Winter Park, Florida

Dr. A. P. Dachnowski-Stokes
Riverside, California

Dr. R. O. E. Davis, U.S.D.A.
Washington, D. C.

Mr. William A. Desnoyers
Belle Glade, Florida

Dr. John C. Gifford
Coconut Grove, Florida

Mr. W. B. Granger
Belle Glade, Florida

Dr. G. B. Sartoris
Washington, D. C.

Mr. Frank Stirling
Ft. Landerdale, Florida

Mr. W. E. Stokes
Gainesville, Florida

Mr. L. L. Stuckey
Pahokee, Florida

Mr. Arthur E. Taylor (4-3-47)
U.S.D.A., Washington, D.C.

Mr. B. McE. Whitlock
Palm Beach, Florida

By the Resolutions Committee,
Luther Jones, Chairman.

William A. Desnoyers

On the afternoon of October 13th, 1948, in the course of a demonstration of airborne spray equipment in the Clewiston-Moore Haven area, Mr. Desnoyers was so unfortunate as to take a position directly in the line of flight of the spray plane, apparently with the idea of photographing the equipment in action both as it approached his position and as it left it.

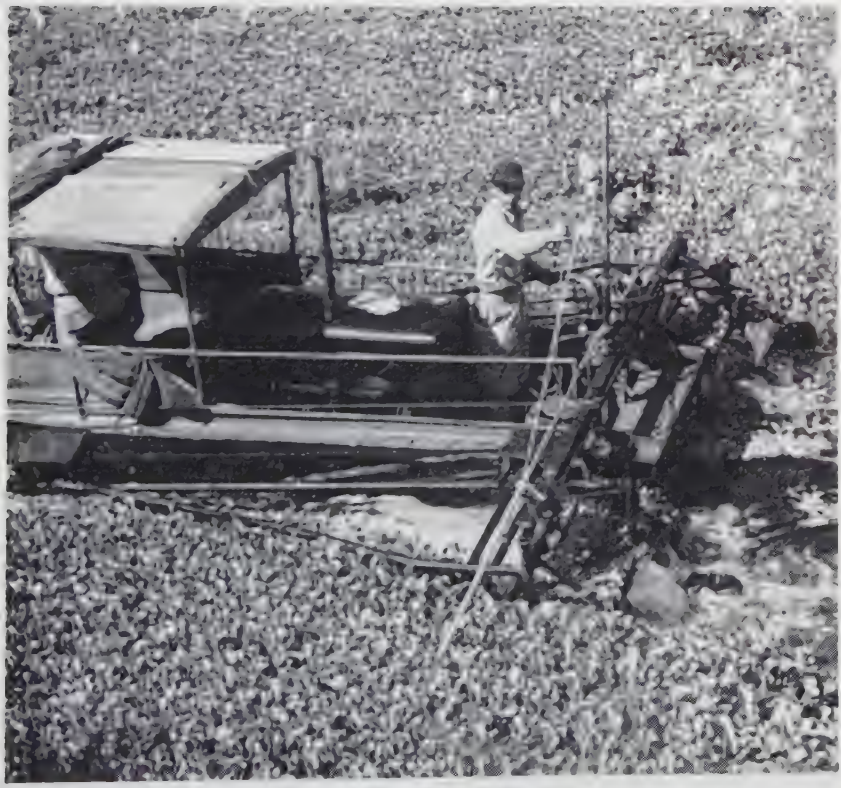
The suddenness of his decision to do this must be obvious from the fact that he must have taken the position after the plane (an N3N biplane) had fully completed its turn and settled down towards the run that had been decided upon for the demonstration; for the pilot could not possibly see an object directly in his immediate path at such a time, especially after he had viewed the run as fully clear at the turn.

While a critical examination of the plane following the accident failed completely to show the place or nature of the impact, death was instant.

In commenting on this tragic happening, Mr. Leo. L. Burnet, Chief, Engineering Division, Jacksonville District, Corps of Engineers, had the following to say:

> "This office was indeed sorry to hear of the fatal accident to Mr. William Desnoyers. Inasmuch as he had worked alongside of several of the people from our office in the experimental work on hyacinths at Mulberry, this office in a measure shares with you in this loss.
>
> "Inclosed is a photograph of Mr. Desnoyers operating spray equipment from the stern of a hyacinth- destroyer boat at Mulberry, Fla., in April of this year. In view of his interest and contribution to the work on water hyacinth control investigatigations, it is thought his family might like this picture."

It is in view of Mr. Burnet's thoughtful suggestion and contribution of the photograph that it is published in these Proceedings, the original copy having been sent to Mr. Desnoyers' family along with this attendant record.



Mr. William A. Desnoyers operating spray equipment from a hyacinth cutter in a cooperative study with the Corps of Engineers, U. S. Army, in the Mulberry (Fla.) area.

HORACE A. BESTOR

OFFICERS OF THE SOCIETY

1946-47

HORACE A. BESTOR (Clewiston) ..... President

LEWIS H. ROGERS (Gainesville) ..... Vice President

HERMAN GUNTER (Tallahassee) ..... Mbr. Exec. Committee

R. V. ALLISON (Belle Glade) ..... Secretary-Treasurer

APPENDIX

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THE HYACINTH ERADICATION PROGRAM OF EVERGLADES DRAINAGE DISTRICT, FLORIDA, 1946-1948

General Area

The main body of organic soils of the Everglades extends from Lake Okeechobee to the southernmost tip of Florida. This area is approximately 40 miles wide and 100 miles long and is bounded on the east and west by mineral soils of higher elevation. This flat expanse of organic soils was originally the natural floodway for the overflow of Lake Okeechobee and the runoff of the surrounding higher lands.

In the process of reclamation, canals were constructed from Lake Okeechobee in an easterly and southeasterly direction to a connection with short coastal rivers, or other natural outlets, discharging into the Atlantic Ocean. These main arterial canals were four in number, varying in length from 40 to 80 miles and in width from 60 to 110 feet. Several smaller east-west canals complete the arterial system of canals, now independent of the control system for Lake Okeechobee.

By 1946 the existing arterial canal system had become choked with hyacinths and reduced approximately 50% in efficiency. Because of the inadequacy of this system to serve agricultural development, and because monies for structural improvement of the system were not in prospect, a hyacinth clearance program seemed the only way to increase the efficiency of the system within the means available.

The Arterial System—Then and Now

Two years ago, mid-year 1946, the total arterial canal system was largely overgrown with water hyacinths. For years these plants had flourished almost undisturbed even by serious frost-kill. Maintenance had almost ceased after the bankruptcy of Everglades Drainage District in 1930. The hardy growth of plants, generally 24″ to 36″ in height, had created a matted root blanket from bank to bank that continued for miles along most of the canals. Few places in the world, if any, can excel the Everglades in ideal growing conditions for the water hyacinth.

The only exceptions to this general rule were the lower reaches of the Miami Canal, where infestation had never been serious for some reason, and in the West Palm Beach Canal. The latter canal was only about 70% covered because of efforts in prior years, by the District and other agencies, to keep the channel open by "drifting."

The history of the water hyacinth in the arterial canal system of the Everglades is a comparatively short one. Contami-

nation began as soon as the canals were connected with Lake Okeechobee, generally about 1918. During the next ten years the use of the channels for navigation supplied some degree of control. However, by the middle 1920's it was necessary to equip a clamshell dredge with a special bucket for occasional use in clearing hyacinth jams from the channels. With the construction of highways into the Everglades, the use of the canals for navigation rapidly decreased. The financial difficulties of the District after 1930 removed the last block to the hyacinth's expansion and the canals were soon covered.

By 1935 means were being sought to clear the canals to provide better drainage. In 1934 and 1935, the Port of Palm Beach District spent approximately $10,000. on hyacinths in the West Palm Beach Canal in an effort to maintain navigation for the transport of materials used in the construction of control structures in the U. S. Government Levee around Lake Okeechobee. In 1936 the Works Progress Administration and the State Road Department cooperated in an expenditure of several thousands of dollars to remove the hyacinths from this same canal. This project was interrupted by the U. S. Engineers in objecting to the discharge of hyacinths into Lake Worth and the Inland Waterway. The U. S. Engineers, in 1939, made available the sum of $10,000. to clear the West Palm Beach Canal of hyacinths provided Everglades Drainage District would agree to maintain the channel clear thereafter. The District agreed and the project was undertaken. The U. S. Engineers, in 1940, also cleared 8 miles of the upper Hillsboro Canal, 18½ miles of the upper North New River Canal and 12 miles of the upper Miami Canal. After this clean-out, the District and the Engineers agreed to maintain specified parts of each cleared section in a clean condition thereafter. Both agencies failed in this agreement.

After the District's defaulted indebtedness was settled, and limited funds were again available for maintenance work, the District tried to improve the hyacinth situation. In 1943 and 1944 approximately $6,000. were expended annually on hyacinth control. In 1945 approximately $9,000. were expended. The bulk of this work was done on the West Palm Beach, North New River and Bolles Canals. The method of control generally used was drifting the hyacinths downstream into the ocean, although a limited amount of removal by dragline equipment was undertaken. An experimental stretch of one-half mile of hyacinths was removed from the Hillsboro in 1944, at a cost of $1,647.00. Much of the expenditure during these three years was on the West Palm Beach Canal in a losing battle to maintain an open channel in the canal.

The picture today is entirely changed. The arterial canals are nearer being free of hyacinths than at any time since the middle 1920's. The channels of the three major canals are entirely free of hyacinth jams, even at the many obstructing bridges. The only jams that cannot be eliminated are those near

the upper ends of the canals where booms have been constructed to prevent infiltration of hyacinth from Lake Okeechobee. Only the occasional hyacinth plant or small group of plants remain to receive the attention of the patrol boats in the routine control program in these canals.

The District's Hyacinth Program

Chronology—

Spring, 1945—Everglades Experiment Station made first tests with 2, 4-D (2, 4-dichlorophenoxyacetic acid) on hyacinths in Hillsboro canal and found it entirely effective.
Fall, 1945—Everglades Experiment Station expanded experiments with 2, 4-D.
March 7, 1946—Appropriation made to Everglades Experiment Station to expand experiments with herbicides.
April, 1946—Experiments expanded to include spraying by aeroplane.
June 6, 1946—Everglades Drainage District authorized project and appropriated funds for program of clearing 178 miles of the main canal system.
June 21, 1946—Crop liability insurance coverage obtained.
June 22, 1946—Contract let for aeroplane spraying of 114 miles of arterial canal.
July 4, 1946—Began aeroplane spraying using diesel oil mix.
July 8, 1946—Began spraying by boat.
Sept. 7, 1946—Second phase of aeroplane spot treatment of jams begun.
Dec. 1, 1946—Seasonal cessation of spray program.
Feb. 1947—Test sprayings for observation of results in early spring.
Mar. 1, 1947—Floods delayed start of spring program.
Mar. 21, 1947—Began spring program.
May 5, 1947—Amphibian "shoes" put to work.
June 1947—In flood emergency, curtailed spray program.
Oct. 1947—Flood emergency halted spray program.
Nov. 7 to Dec. 12, 1947—Limited spraying by boat.
Jan. 17, 1948—Began spring boat spraying program.
March 1948—Began moving remaining jams from major canals.
July 31, 1948—162 of original 178 miles of canal entirely on patrol basis.

Procedure

In the fall of 1945, the Everglades Experiment Station at Belle Glade, Florida, obtained small quantities of 2, 4-D with which to begin experimental work. Most of these materials were in dust form. Some of these limited amounts of materials were used experimentally in distribution by aeroplane on hyacinths in a short section of canal. Results of these early experiments

were encouraging but showed the need of developing the correct method of application and control.

During the next few months many new formulations of 2, 4-D became available for experimental work. Realizing the possibilities of this herbicide as a means of fighting the hyacinth problem, the Board of Commissioners, on March 7, 1946, appropriated $500.00 to be used largely to purchase materials with which to conduct hyacinth experiments. Experimental work with aeroplane spraying was begun extensively in April, 1946. Various formulations of 2, 4-D at different rates were applied.

As a result of these experiments the following basic conclusions were reached that determined the type and scope of the hyacinth eradication program later authorized by the District:

1. That unit for unit of the killing component, sprays were more effective than dust and generally easier to control in application.
2. That a rate of 200 gallons per acre of a spray containing 1000 p.p.m. of 2, 4-D was generally suitable in hyacinth eradication work.
3. That certain types of agricultural plants were very sensitive to 2, 4-D.
4. That 2, 4-D was non-toxic to fish and cattle in the concentrations used.
5. That spraying by aeroplane was feasible and economical of use in hyacinth eradication work on the District's canals.
6. That the use of spray boats to clean up behind the aeroplane and to later patrol the canals was evident.

On June 6, 1946, the Board of Commissioners of Everglades Drainage District authorized a hyacinth program embracing 178 miles of the arterial canal system. Of this total, it was proposed that 114 miles be sprayed by aeroplane and 64 miles by boat. Most of the proposed boat work was on the West Palm Beach canal where efforts at control had been made in prior years and the cover was not as extensive or densely matted. The cost of eradication to reach the patrol stage was estimated at $45.40 per mile or a total of approximately $8,000.00. The program was from time to time extended to cover additional mileage and the estimated cost was much less than actually expended. This estimate is cited in this paper to show what can be expected in the way of cost under optimum conditions that never occurred in the District's program.

Insurance coverage on crop damage as a result of the spray program was obtained June 21, 1946. No claim was ever made under this policy and the premium was reduced 30% after the first year. Obtaining crop liability insurance of this type was difficult as there was no precedent or established rate. This necessarily delayed letting the contract for the spray work.

The contract was entered into the following day, June 22, 1946, at a base rate of $0.75 per acre of hyacinths sprayed. Specifications called for spraying the center area of each canal

"to within a few feet of the channel edge." It was proposed to make the first application at the rate of 750 p.p.m. as compared with the standard rate of 1000 p.p.m. in 200 gallons of water per acre. In the type of aeroplane equipment used, this was the equivalent of 3 pints of 40% 2, 4-D product in 2 gallons of water per acre. The proposed second treatment, to be applied approximately two weeks later, was to be at a rate of from 75% to 100% of the first application, as determined by then existing conditions. As it developed, this rate of application was never followed.

The type of aeroplane equipment used consisted of N3N biplanes powered with a 250 horsepower motor. A spray boom was rigged under the surface of the lower wing and fitted with spray nozzles spaced 18 inches apart on the boom. An operating pressure of 50 pounds per square inch was developed by a small marine gear pump driven by an auxiliary propeller. A 50 gallon tank was mounted in one cockpit of the aeroplane as a supply tank.

The original program of spraying by aeroplane using water as the carrier had several serious weaknesses, the most important of which was the loss of effect of the killing component if it rained on the sprayed area within a few hours after the spray work was completed. Another was the failure to get coverage to the edge of the canal channel. Consideration had been given to oil as a carrier. On July 4, 1946, an experimental stretch of canal was sprayed using No. 2 diesel oil as the carrier. The results were very satisfactory, giving much better coverage and a better kill.

Thereafter diesel oil was used almost entirely. The spray boom was changed to a section of electrical conduit with No. 70 sized holes drilled at 1½ inch intervals. This part of the equipment has again been changed with the availability of better designed nozzles and cut-offs that prevent "drip." After the decision to use oil in the spray, it was found that only one of the formulations of 2, 4-D was miscible in oil. Fortunately we had used this formulation in the experimental work. Emulsifying agents were tried with no success. Unfortunately, the formulation that was miscible in oil was one of the highest priced on the market, but it was considered that the increase in results was worth the additional cost. The price has since been substantially reduced.

These developments changed the original program somewhat. It was found that a smaller dosage obtained satisfactory results. It developed that a complete second application was not the economical method to use. As it resulted, the canals designated for aeroplane spraying were sprayed one time over by August 31, 1946, and the dying hyacinths allowed to sink and clear up as much possible. The aeroplane program was expanded to include nine miles of the upper Miami Canal. In this first phase, 1259 acres, the rate of application averaged 0.8 quart of 40%

butyl ester carried in approximately 3 quarts of No. 2 Diesel oil per acre.

This first application resulted in approximately an 80% kill and the costs were as follows:

Herbicide cost per acre	$2.109
No. 2 Diesel oil cost per acre	0.076
Application cost per acre	0.775
Per Acre Total	$2.958

On July 8, 1946, the boat-spray program was commenced in the West Palm Beach Canal. A flat bottomed "frog-boat" hull powered by a 10 horsepower outboard motor was used. The spray equipment consisted of a conventional 20 g.p.m. orchard spray pump driven by an air-cooled motor, a "boom-type" spray wand and a 50 gallon supply tank. This was a two-man operation. The mixture used was at the rate of 1000 p.p.m., being one pint of 40% formulation of 2, 4-D in 50 gallons of water.

Where there was any open channel in the canal, the boat worked well. At first, it was attempted to force the boat through the hyacinth jams by cutting a path with machetes. This was slow and costly and the procedure evolved into portaging the boat around the jams, spraying where there was any open channel. Later the jams were sprayed by aeroplane.

In early September 1946, the second phase of the aeroplane spray program was begun. Obviously, the existing situation did not permit employment of an aeroplane on an acreage basis. Thereafter, all such spray work was done on an hourly contract agreement.

The condition met here was the result of dead hyacinths sinking and loosening the original matted surface to an extent that permitted both remaining dead hyacinths and live hyacinths to drift with wind and current and form considerable jams at the numerous short-span bridges over the canals. These jams delayed the time that the spray boats could navigate most of the canals in a clean-up program. This added immeasurably to the ultimate cost of the hyacinth eradication program. In contrast to the general condition, the West Palm Beach Canal, where there are few short-span bridges, was substantially on a patrol basis a full year before the other arterial canals.

During this phase of the program, the aeroplane was utilized in spraying the jams as they formed. Regrowth of the hyacinths was a factor and the inability to combat this regrowth successfully was discouraging. The problem accentuated the need of some method of control during the period between the spraying of a covered channel by aeroplane and the opening of a channel that a boat could navigate. A spraying arrangement on the wingtip of the aeroplane was tried without any large degree of success. This problem of control in the interim

between the aeroplane and the boat resulted in the construction of an amphibian machine for this job the following spring.

Cool weather by December 1, 1946, halted the hyacinth spray program. While the plants were not winter-killed they were dormant to the extent that their reaction to the herbicide was unsatisfactory.

In February, as the weather became warmer generally, test experiments were made at several points by the aeroplane to determine at what stage the hyacinths would react sufficiently to the herbicide to justify the cost involved. It was soon learned that we must be content in the spring to wait until the hyacinth is actively growing before it reacts favorably.

On March 1, 1947, a six-inch rainfall blanketed the upper 'Glades, creating floods that delayed the spring program until March 21st. Beginning on that date, the aeroplane began the spraying of jams in the channel and the boat began the routine spraying of the edges of the West Palm Beach Canal. A second boat was put in operation equipped with a 12 g.p.m. orchard spray pump. Some infiltration of hyacinths from connecting ditches and borrow pits occurred during this early flood, but to no serious extent.

The amphibian spray machine was ready for its part of the program on May 5, 1947, after being constructed in the shops of the Everglades Experiment Station at Belle Glade, with the assistance of the Station's personnel. This contrivance was assembled from a three-quarter ton four wheel drive chassis and wheels constructed from 6'-6" diameter pressed steel telephone cable reels. The face of the reels was banded with marine plywood to provide flotation for the vehicle within the wheels. Flotation being in the wheels, the rig was promptly dubbed "Jesus Shoes." A six horsepower air-cooled motor powers the vehicle, driving through a 15:1 reduction gear ahead of the conventional transmission. The spray equipment comprises a 12 g.p.m. orchard spray pump powered by an air-cooled motor, a 50 gallon supply tank and broom type spray wand. This also is a two-man operation piece of equipment.

In operation, this machine demonstrates its place in the program. It travels over jammed hyacinths easily and is reasonably dependable. It is adaptable to any problem where aeroplanes cannot spray and the boat cannot navigate.

By the last of June the District was in flood difficulties. The spray program was curtailed; in fact, it was entirely stopped at times. Canals were generally out of their banks, making effective spraying impractical. Most expenditures during July were for removing jams of dead hyacinths from each bridge location in the interest of better flood discharge.

The peak of the flood was reached near the middle of October, 1947, and all spray work was stopped. The Everglades were almost entirely under water to a depth of two or three feet and a general overland flow to the south and southeast resulted. Hya-

cinths from many farm and levee ditches floated with the flood crest and drifted with the currents. As most of the arterial canals have a roadway on their south or southwest banks, the drifting hyacinths collected in the canal channels. Efforts were directed toward keeping serious hyacinth jams from forming at the numerous bridges and controls in the canals in order that the channels could operate as efficiently as possible. The cost of this work has been charged against the hyacinth program, but it is possbile that the correct charge would have been to flood emergency.

It is impossible to evaluate the benefit of the hyacinth program to the Everglades during the 1947 flood. It is a fact that the arterial channels were even then considerably more efficient at comparable stages within the channel than they were when they were blanketed with an extensive hyacinth mat. How the hyacinth blanket would have influenced the channel action with the banks submerged from two to three feet generally is a debatable point. It is certain that a decrease of overland flow southward would have resulted if the hyacinths had been available in sufficient quantities to block the openings in that direction. Jams at bridges and controls would undoubtedly have been a serious threat to canal blockage and a greater danger of probable damage to the structures themselves. Without question, had the 1947 flood occurred two years earlier, the duration of the flood would have been longer and stages generally higher.

Spraying by boat was again undertaken on November 7th in an attempt to keep the natural growth and spread of the hyacinths in the canal under control. As the canal banks were still flooded this work was not too effective but was continued until December 12th when cooler weather produced a mild degree of dormancy in the hyacinth plants.

The spring spraying program for 1948 was begun on January 17th. The winter had been mild and the warm weather in January caused the hyacinths to begin to grow. The canals were within their banks and the hyacinths once more confined to the channel. From a standpoint of progress, the program was only slightly advanced from the stage it occupied in the spring of 1947. The channels were generally bordered along their edges by a fringe of hyacinths and extensive jams were numerous, especially at bridge crossings of the channel. However, some of these jams were loosely packed and could be traversed by boat without too great a difficulty.

Profiting by the experience obtained in 1947, efforts were concentrated on one canal at a time to clear that particular channel to navigation by spray boat. Three boats were normally used but two boats and the "Shoes" sometimes made up the spray team. One boat patrolled the channels or parts of channels as they were cleaned and in need of patrol spraying. At the beginning of the year, the West Palm Beach Canal was the only channel navigable by spray boat throughout its length.

As each canal was sprayed and the dying hyacinths began drifting downstream to collect at bridges and controls, a crew of men was used on a full time basis to keep the jams broken up and drifting toward the ocean. This operation was costly but was justified by the results, for as soon as a channel was cleared of jams to permit free passage of the spray boats, the main fight was over.

Cost of the Program To Date

The following annual and total cost reflects all cost except general office supervision. Most overhead costs, as crop liability insurance, are included. Many labor items are included that possibly are chargeable to flood emergency work, but were too involved to separate.

ANALYSIS OF COST OF HYACINTH PROGRAM BY EVERGLADES DRAINAGE DISTRICT

A—Materials and Equipment

Year	2, 4-D Spray Materials	No. 2 Diesel Oil	Equipment and Repairs	Aeroplane Contract	Experimental Work	Annual Total
1946	$6,217.98	$245.15	$2,553.76	$2,495.55	$428.15	$11,940.59
1947	9,018.76	347.34	2,526.89	3,273.15		15,166.14
1948 (7 mos.)	4,537.45	21.45	895.40	241.66		5,695.96
Totals	$19,774.19	$613.94	$5,976.05	$6,010.36	$428.15	$32,802.69

B—Labor

Year	Boat and Shoes Spraying	Removing and Drifting Jams	Field Supervision	Miscel. Labor on Equipment	Annual Total
1946 (6 mos.)	$ 1,516.00	$ 467.00	$ 120.00		$ 2,103.00
1947	3,690.83	1,852.68	840.00	$165.00	6,549.18
1948 (7 mos.)	4,832.44	2,874.57	1,410.00	475.00	9,592.01
Totals	$10,039.27	$5,194.25	$2,370.67	$640.00	$18,244.19

C—Summary

Year	Materials and Equipment	Labor	Annual Total
1946	$11,940.59	$ 2,103.00	$14,043.59
1947	15,166.14	6,549.18	21,715.32
1948	5,695.96	9,592.01	15,287.97
Totals	$32,802.69	$18,244.19	$51,046.88

For the amount expended the following channels have been cleared and are on a patrol program basis:

Canal	Width in Feet	Length in Miles	Remarks
West Palm Beach	65-110	40	Original Program
Hillsboro	60-100	50	Original Program
North New River	60-100	59	Original Program
Cross Canal	35-60	13	Original Program
South New River	60-90	7	Expanded Program
Dania Cutoff	60-90	4	Expanded Program
Big Mound	35-60	4	Expanded Program
	Total	177 Miles	

In addition, 16 miles of the Bolles Canal and 8 miles of the upper Miami Canal are partially cleared. Work now being done to place these canals on a patrol basis should be completed this year.

THE DISTRICT'S FUTURE HYACINTH PROGRAM

It is the objective of the Board of Commissioners of Everglades Drainage District to extend the hyacinth eradication program as funds become available until the entire canal system of the District has been cleared. Constant patrol work is necessary if the channels are to remain cleared and plans are in process for the accomplishment of that part of the program as economically as possible. The cost of the patrol work is estimated to cost less annually than the $9,000. spent on hyacinth work in 1945—the last full year before spraying began. As more ditches and canals connecting with the arterial system are cleaned, outside infestation to the District's canal should lessen and the cost of patrol operation decrease.

A new type of spray boat is now being constructed for patrol work. The hull is of light framework covered with marine plywood. It will be powered with a 5 horsepower outboard motor. The spray equipment will be a low pressure, low volume type using a small gear pump and small air-cooled motor. The type of boom or wand must still be determined by trial and error, but will probably be a wand about nine feet in length with selective nozzles. This equipment will be one-man operated and it is proposed to work the boats in pairs to reduce cross-drift of hyacinths by wind during the spraying period.

WORK BY OTHER AGENCIES AND INDIVIDUALS

Throughout the Everglades numerous sub-districts and individuals have initiated spray projects on a smaller scale in the secondary canal system. Each undertaking encountered its own problems, but results have been generally satisfactory. All types of spraying equipment are being used, including the aeroplane and the boat. Much of the work in the smaller channels has been accomplished by land equipment spraying from the banks. Good work has been accomplished, but the need of periodic maintenance spraying to keep the channels clean has not been recognized in many instances.

Dade County has aided the Everglades Drainage District by including in their spray project 40 miles of the District's secondary canal system. In addition, 16 miles of coastal canals and ditches have been sprayed. In its work, this county utilized an army "duck" to some extent for a part of the work, but are now using a boat as the vehicle.

CONCLUSION

The District's program is visible evidence of the feasibility

of clearing channels and controlling water hyacinths by spraying with 2, 4-D.

The cost to the District has been greater than originally estimated for three reasons:

1. The experimental nature of the project.
2. Inability to forsee the problems that would be caused by jams at bridges and other channel obstructions, preventing early clean-up of the edges by boat spraying.
3. Delay and infestation caused by the 1947 flood.

It is evident that diligent patrol of a channel is necessary to maintain the channel in a clean condition. This patrol should be at intervals that prevents the maturity of a new seed crop. It is also evident that regrowth from rhizomes is almost absent in the young plant after it is sprayed, which is contrary to the reaction in old, vigorous plants.

It is evident that legislation will be required to protect channels that are being patrolled from deliberate contamination from connecting streams and lakes.

Research developing a chemical formulation that would speed the rotting and disintegration of the dead hyacinths would hasten the opportunity for boat clean-up and be helpful in any program. In the Everglades, a spray formulation that would kill and control Para grass would permit further clean-up of channels and farm ditches to the benefit of the whole program. This is also true of several aquatics that are a part of South Florida's problem.

Expansion of any hyacinth eradication program to embrace an entire watershed area would be the economical way to combat hyacinths from the long-range viewpoint. The experience gained by the District's project indicates that regrowth lessens with systematic patrol and it is believed that complete eradication is not an impossibility within a complete waterway system.

BOARD OF COMMISSIONERS
EVERGLADES DRAINAGE DISTRICT

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